A DESCRIPTION

OF

ACTIVE AND EXTINCT

VOLCANOS.

In the present state of geological science, a mineralogist could hardly employ himself better, than in traversing those ambiguous countries where so much has been ascribed to the ancient operation of volcanic fire, and marking out what belongs clearly to the erupted or unerupted lavas, and what parts are of doubtful formation, containing no mark by which they may be referred to the one of these, more than to the other. Such a work would contribute very materially to illustrate the Natural History of the Earth.—*Illustrations of Hutton's Theory.*

A DESCRIPTION

OF

ACTIVE AND EXTINCT

VOLCANOS,

OF

EARTHQUAKES, AND OF THERMAL SPRINGS;

WITH REMARKS ON

THE CAUSES OF THESE PHÆNOMENA,

THE CHARACTER OF THEIR RESPECTIVE PRODUCTS,

AND

THEIR INFLUENCE ON THE PAST AND PRESENT

CONDITION OF THE GLOBE.

BY CHARLES DAUBENY, M.D., F.R.S.,

FELLOW OF THE GEOLOGICAL AND LINNÆAN SOCIETIES;
HONORARY MEMBER OF THE ROYAL IRISH ACADEMY, AND OF THE ROYAL AGRICULTURAL
SOCIETY OF ENGLAND; OF THE SOCIETIES OF QUEBEC, MONTREAL, PHILADELPHIA,
AND BOSTON; OF THE ACADEMY OF GENEVA; CORRESPONDING ASSOCIATE
OF THE GIOENIAN SOCIETY OF NATURAL HISTORY AT CATANIA, ETC.;
PROFESSOR OF CHEMISTRY AND OF BOTANY IN THE UNIVERSITY OF OXFORD.

Πολλὰ δ' ἔνερθ' ὕδεος πύρα καίεται.

SECOND EDITION, GREATLY ENLARGED.

LONDON:
RICHARD AND JOHN E. TAYLOR,
RED LION COURT, FLEET STREET.
1848.

ALERE FLAMMAM.

PRINTED BY RICHARD AND JOHN E. TAYLOR,
RED LION COURT, FLEET STREET.

TO

JOHN KIDD, M.D., F.R.S.,

REGIUS PROFESSOR OF MEDICINE AT OXFORD,

AND TO

THE VERY REV. WILLIAM BUCKLAND, D.D., F.R.S.,

DEAN OF WESTMINSTER,

PROFESSOR OF GEOLOGY AND MINERALOGY AT OXFORD, ETC. ETC.

MY DEAR FRIENDS,

THE lapse of twenty years has only served to strengthen in my mind those sentiments which induced me to dedicate to you, conjointly, the former Edition of this Work.

Regarding, which I have never ceased to do, Chemistry as the Grammar of all those Natural Sciences with which I can pretend to an acquaintance, it is no less my desire now than heretofore to express the gratitude I feel to the Individual who was my first Instructor in that fascinating Study; and unimportant as may have been the Fruits culled by myself during occasional and somewhat desultory incursions into the regions of Geology, I ought not to leave out of the account the benefit I have each time derived, after several months of sedentary occupation, from change of scene and a more active mode of life, in estimating

what I owe to a Pursuit, which holds out the strongest inducements to both.

Thus am I every year reminded of the obligations I am under to the Professor, whose animated pictures of the early History of the Globe, and of its successive Revolutions, first awakened my attention to this branch of Natural History, and thus not only opened to me a new and interesting Department of Chemical Research, but also supplied me with a powerful incentive to foreign travel, and to healthful bodily exertion.

In inscribing therefore these results of my labours in the field of Physical Research, to those who first taught me to reap the Harvest it affords, and even to handle the implements of my Craft, I am doing not only what is grateful to my own feelings but just also towards yourselves; and it is my hope, that the same lapse of years, which has given to you both a more extended reputation and a higher position amongst Men of Science, may likewise have enabled me to present you with a less inappropriate homage, by so maturing my knowledge, as to render the present Edition of this Work at once more accurate in its details, and more comprehensive in its general outline, than the one that preceded it.

I remain,

My dear Friends,

Yours most faithfully,

CHARLES DAUBENY.

Oxford, Nov. 30, 1847.

PREFACE

TO THE FIRST EDITION.

THE circumstance of a work like the present proceeding from a Professor of Chemistry seems to call for some explanation; for notwithstanding the near connexion that subsists between the latter Science and every Department of Geological inquiry, yet it must be confessed, that the Study of Volcanos embraces in itself a field of such extent, that it ought to be entered upon as a principal, rather than as a subordinate occupation.

It is fair therefore to myself to mention, that the subject was first taken up at a time when there appeared a reasonable prospect of my obtaining an appointment, which would have entailed the necessity of a five years' absence from my native country.

The appointment in question I indeed ultimately lost, owing, as it was understood, to certain doubts that had been started with regard to my eligibility as a Candidate; but, as I had already formed the plan, and in some degree advanced in the details of the inquiry, I continued to prosecute it at intervals, not only for several years after my hopes of the situation alluded to had been frustrated, but even at a time when the office I afterwards obtained in the University of Oxford might have rendered a somewhat different line of pursuits more appropriate.

I have been obliged however in consequence to curtail in a considerable degree the scheme I had formed, which comprehended originally an examination of the Volcanos in the New, as well as of those in the Old World; and am under the necessity of now bringing forwards as a compilation, many parts of the work in which I had intended to introduce nothing but original matter.

It is satisfactory for me however to reflect, that I have visited most of the principal localities in Europe, noticed in my first two Lectures* as the seats of volcanic action, so that with respect to them, even where facts are stated which did not fall within the compass of my own observation, I have been able to ascertain, by going over the same ground, what degree of credit is due to the individuals on whose authority they are given.

In treating of the other Quarters of the Globe in which Volcanos occur, I have spared no pains in availing myself, to the best of my ability, of those resources, which a proximity to extensive public libraries has placed at my disposal, and therefore hope that this part of the work at least may be of use to future travellers; not merely by putting before them what is already ascertained, but likewise by directing their attention to those points which still require investigation.

I venture therefore to offer these Lectures as supplying in some degree, even in their imperfect state, a deficiency long felt in the geological literature of Great Britain; no treatise on the subject of Volcanos having appeared in this language since that of the Abbé Ordinaire, except indeed the recent publication of Mr. Poulett Scrope, which, though containing many ingenious views on the theoretical parts of the subject, is not calculated to supersede the demand for another work, expressly designed to convey a detailed statement of facts,

* Comprising what now occupies the first 300 pages of the Work.

with regard to the characters and situation of the rocks which owe their origin to subterraneous fire.

I have only further to add, that the remarks, made at the commencement of the First Lecture, with respect to the little attention that has been paid in Great Britain to the Department of Geology which forms the subject of this work, must be understood as applying solely to that portion of it which relates to Products confessedly Volcanic; for in no country have more important lights been thrown on the nature of Trap and Basaltic Districts, than by the labours of Dr. Macculloch and of other English Geologists*; to some of whom I feel personally indebted, either for much of the information which forms the groundwork of such an inquiry, or for the friendly assistance afforded me in the prosecution of it.

* See particularly the Memoir on the Coast of Antrim, by my friends the Rev. W. Buckland and W. Conybeare, in the third volume of the Geological Transactions, supplementary to Dr. Berger's paper on the same district.

PREFACE

TO THE SECOND EDITION.

If any apology be thought requisite for reviving at the present time a Treatise that has for many years past been out of print, the mere reference to its present as compared with its original bulk may, it is conceived, suggest reasons that will appear satisfactory.

That this increase in its size has not arisen from a more diffuse or discursive mode of writing, will be manifest from a very cursory examination of its contents; indeed, it may be perceived, that the facts are presented in a more condensed form than heretofore; that much of what appeared less relevant to the subject has been curtailed or omitted; and that every effort has been made by the Printer to economise space, by bringing the lines into closer juxtaposition, and by the substitution of a smaller type for the less important portion of the details.

Such, nevertheless, have been the accessions to the mass of our information on the subjects discussed in this Volume which the last twenty years have produced, that whereas in the former Edition the Descriptive Portion occupied only 352 loosely printed pages, in the present it has swollen to no less than 503; and that the General Remarks on Volcanic Phænomena, which were heretofore comprised within 80 pages, have now extended themselves to 110.

Moreover, a still further increase to the size of the volume has been occasioned by my regarding, as Departments of Volcanic Geology, Earthquakes and Thermal Springs, phænomena passed over in a very cursory manner in the former Edition, but occupying nearly 100 pages in the present.

In this extension of my design it would have been manifestly absurd to have retained the division into Lectures, in which form the original draft or outline of my Work was moulded: but it will be seen that the same arrangement of the materials is still persevered in, as being, it is conceived, convenient, both in enabling the Reader to grapple with the facts, before his mind is biassed with the hypotheses, and also in rendering the Volume capable of serving as a kind of Guide-book to the Explorers of Districts in which Volcanic phænomena occur abroad, no less than as a Storehouse of Facts for those who reason upon them at home.

In short, if in the imperfect and immature form in which it originally appeared—before the researches of Darwin, of Abich, of Elie de Beaumont, and of a whole host of other Geological travellers, had shed so much light upon the phænomena of Volcanos—my Work met with a favourable reception*, as well as a ready sale, it may be offered to the Public with some degree of confidence now, when the subject itself comes invested with a new interest, owing to the connexion between the present phænomena of Volcanos and the past as well as future Revolutions of our Planet, that has been substantiated through the important contributions which the persons above-mentioned and so many other of their fellow-labourers have rendered to Science.

By thus drawing largely from the Investigations of others, as well as from the Memoirs on Volcanic Geology which I have

* See especially the Edinburgh Review for March 1827.

myself communicated to various Societies since the first publication of this Treatise, it has been my endeavour to incorporate with the original materials whatever had been added of any value to our stock of knowledge on this subject during the years that have since elapsed; and although I have not seen reason to abandon the views with which I started, either with respect to the probable cause of volcanic action, or the mode of its operation, my readers, it is conceived, will find the means of correcting my errors on these points placed within their reach, by the faithful report of the phænomena themselves which is presented to their consideration.

In a word, whilst avoiding, as much as possible, to challenge controversy, I have been far from keeping out of sight, and have rather aimed at giving a *prominence* to, such statements and expositions of facts as seemed least in accordance with the Geological opinions now in vogue, thus labouring, so far as in me lies, to correct that one-sidedness of mental vision which is apt to be engendered, by contemplating exclusively one class of geological agents, and by regarding the truths of Science under certain particular aspects.

Above all, it has been my wish to attach to Chemical considerations their just and proper weight, confident that if I can succeed in so doing, I shall be rewarded by the satisfaction of having enlisted in the cause of Geology a potent and too much neglected Ally, even though it should, as is very possible, supply weapons to others for the demolition of the theories that I have myself aimed at constructing by its aid.

Nov. 30, 1847.

CONTENTS.

PART I.

DESCRIPTIVE PORTION.

CHAPTER I.

CHAPTER II.

GENERAL NATURE OF VOLCANIC ACTION.

CHAPTER III.

ON THE VOLCANOS OF FRANCE.

CHAPTER VII.

VOLCANIC ROCKS OF STYRIA.

CHAPTER VIII.

VOLCANIC ROCKS OF NORTHERN ITALY.

CHAPTER IX.

CENTRAL ITALY.

CHAPTER X.

SOUTHERN ITALY.

CHAPTER XI.

VOLCANOS OF SOUTHERN ITALY (*continued*).

CHAPTER XII.

SOUTHERN ITALY (*continued*).

CHAPTER XIII.

ISLANDS OF PROCIDA AND ISCHIA.

CHAPTER XIV.

LIPARI GROUP OF ISLANDS.

CHAPTER XV.

VOLCANIC ROCKS OF SICILY, ETC.

CHAPTER XVI.

SARDINIA—SPAIN—PORTUGAL.

CHAPTER XVII.

VOLCANOS OF ICELAND.

CHAPTER XVIII.

GRECIAN ARCHIPELAGO.

CHAPTER XIX.

ASIA MINOR.

CHAPTER XX.

SYRIA, THE HOLY LAND, AND ARABIA.

CHAPTER XXI.

VOLCANIC PHÆNOMENA OF PERSIA AND THE ADJOINING COUNTRIES.

CHAPTER XXII.

VOLCANOS OF CENTRAL ASIA.

CHAPTER XXIII.

VOLCANOS OF KAMTSCHATKA AND THE CHINESE SEAS.

CHAPTER XXIV.

INDIAN ARCHIPELAGO.

CHAPTER XXV.

ISLANDS IN THE PACIFIC OCEAN.

CHAPTER XXVI.

ISLANDS ON THE EASTERN COAST OF AFRICA.

CHAPTER XXVII.

AFRICAN CONTINENT.

CHAPTER XXVIII.

ISLANDS LYING TO THE WEST OF AFRICA.

CHAPTER XXIX.

WEST INDIAN ARCHIPELAGO.

CHAPTER XXX.

VOLCANOS OF NORTH AMERICA, OR ABOVE THE ISTHMUS OF DARIEN.

CHAPTER XXXI.

VOLCANOS OF SOUTH AMERICA, OR SOUTH OF THE ISTHMUS OF DARIEN.

PART II.

ON PHÆNOMENA NOT IMMEDIATELY ARISING FROM VOLCANOS, BUT SUPPOSED TO BE CONNECTED WITH THEM.

CHAPTER XXXII.

ON EARTHQUAKES.

CHAPTER XXXIII.

ON EARTHQUAKES.

CHAPTER XXXIV.

THERMAL SPRINGS—THEIR GEOLOGICAL POSITION.

CHAPTER XXXV.

THERMAL WATERS, THEIR GASEOUS IMPREGNATION, ETC.

PART III.

DEDUCTIONS FROM THE FOREGOING FACTS: WITH REFERENCE TO THE CAUSES OF VOLCANOS; THE CIRCUMSTANCES THAT INFLUENCE THE CHARACTER OF THEIR PRODUCTS; AND THE USES THEY FULFIL IN THE ECONOMY OF NATURE.

CHAPTER XXXVI.

GENERAL STATEMENT OF THE VARIOUS THEORIES BY MEANS OF WHICH THE OPERATIONS OF VOLCANOS HAVE BEEN ACCOUNTED FOR.

Page

CHAPTER XXXVII.

GENERAL INFERENCES RESPECTING THE LAWS OR CONDITIONS OF VOLCANIC ACTION.

CHAPTER XXXVIII.

COMPARATIVE ESTIMATE OF THE MECHANICAL AND CHEMICAL THEORIES.

CHAPTER XLI.

FINAL CAUSES OF VOLCANOS.

APPENDIX,

CONTAINING ADDITIONAL NOTES, AND LIST OF WORKS ON VOLCANOS, EARTHQUAKES, AND THERMAL WATERS.

LIST OF PLATES AND MAPS.

PLATES.

MAPS.

ON VOLCANOS.

CHAPTER I.

INTRODUCTORY REMARKS.

IT cannot fail to be a source of satisfaction to those who, like the Author of this Treatise, have watched with some interest the progress of Geology for more than a quarter of a century, to observe not only the enormous accumulation of facts bearing upon the subject-matter of the science itself which have been amassed within that period, but also the advance that has been made in the meanwhile towards the settlement of some of those important problems which stand, as it were, at the very threshold of all inquiries of this description.

Thus we need not go further back than to the Geological Essay* of my respected predecessor in the Chair of Chemistry in my own University, to be reminded, that within the last thirty years it was still considered a subject of doubt whether the phænomena, which an examination of the earth's crust had shown to have been manifested in former ages, were the same in kind with any of those that are taking place at present, or whether they involve the supposition of a totally distinct system of causes, which since the commencement of the existing order of things have ceased to operate.

The observations made subsequently to the period alluded to, and the discussions that followed in their train, have at

* Kidd's Geological Essay, Oxford, 1815.

least so fär narrowed the field of controversy, as that the fixity of the laws of nature through all time, as over all space, is regarded as an axiom in all systems of cosmogony, and that the only question upon which any further dispute can arise now is, whether the limited range which our observations embrace, does in fact justify us in pronouncing, that the phænomena which have occurred formerly cannot have exceeded in magnitude and extent those which we see taking place before our eyes.

Thus, for instance, instead of vaguely referring, as heretofore, the excavation of valleys and the distribution of erratic blocks to the operation of one universal Deluge, a catastrophe, which if brought about by supernatural agency lies beyond the field of our investigations, and if through the instrumentality of natural agents, would imply a mode of action different from anything we have ever experienced, geologists of the present day are principally occupied in searching for processes now going on, in order to explain the appearances alluded to, and seem only divided as to the question of the possibility of referring them to the action of existing streams, and to such floods as may have occurred in the country within the memory of man, or to the bursting of lakes, the melting of icebergs, the descent of glaciers and other events, which though not observed, at least within the limits of the district under examination, are nevertheless all reducible to the agency of natural forces.

The same progress seems to have been made towards the solution of those geological phænomena which depend upon the operation of igneous causes; for whilst, at a period not very remote, the existence of granitic and trappean rocks was referred to processes which, to say the least, implied a mode of action bearing no relation or analogy to anything actually taking place, we are now at least agreed in ascribing such formations to the operation of causes similar to those which at present manifest themselves in volcanos and in earthquakes, modified only by certain differences in the conditions under which these forces were exerted.

For the full recognition of this Principle, as well as for the development of the important consequences following from its adoption, we are much indebted to the highly philosophical

work of Mr. Lyell, which appeared since the publication of the first edition of this present Treatise, although it may be seen by reference to the latter, that whilst the limited experience I possessed on geological subjects in general would have rendered it an act of presumption on my part to dispute, as Mr. Lyell has done, the conclusions that had been previously arrived at by others with respect to those phænomena which imply the action of water, I had at least stood out for the principle of the unvarying operation of the laws of nature so far as regarded those igneous operations which I had made my principal study. Accordingly the professed object of my Treatise was stated to be that of bringing together from various sources, facts relating to the operation and effects of volcanos and of earthquakes, such as might serve as *data* by means of which to account for the appearances exhibited by the granitic and trappean rocks produced at former periods of the earth's history.

Indeed, even so long ago as the year 1816, when pursuing my studies at Edinburgh, I was led to meditate the excursions which brought me to the above conclusions, and which were undertaken in the first instance principally as a means of ascertaining whether trap rocks were of igneous origin or not.

At that period the authority of Professor Jameson, whose lectures I was attending, was calculated to impart to his class a bias in favour of the doctrines of the school of Werner, although I was never so far a convert to the opinions alluded to, as not to entertain misgivings with respect to the conclusions that this geologist and his disciples had in that instance arrived at, and not to feel a persuasion that for the sake of determining whether trap rocks owed their origin to fire, the most effectual method would be that of comparing them in all their details with products universally acknowledged to be volcanic.

I perceived that for this purpose a mere examination of hand-specimens was not sufficient—the spots themselves should be visited, and the circumstances of geological position as well as the nature of the rocks associated must be carefully compared with what had been observed in those

trap districts which had excited so much attention and dispute.

I could not help wondering that such an inquiry, intimately connected as it was with the basaltic question, should never have been taken up by any of the zealous supporters of either system; that the volcanos of Auvergne, for instance, should be known to us chiefly through a French work of rather an old date*, or a short German tract of Von Buch's†, and that of the reputed volcanos of Hungary we should possess absolutely no authentic account‡, since one author represented the whole country as of aqueous origin §, whilst another described the very craters from whence the lava was ejected ||.

A visit to Auvergne in the year 1818 was the first step taken by me towards carrying out the inquiries thus projected, and the result of them was that of speedily bringing me to the conclusions which I stated in my Letters to Professor Jameson, published in his Journal in 1819, and afterwards embodied in my general Treatise on Volcanos, the interval up to the time of the appearance of this latter work in 1826 having been occupied, not so much in hunting for further

* Montlosier sur les Volcans d'Auvergne, 1802.

† Mineralogische Briefe aus Auvergne, in the 2nd volume of his Geognostische Beobachtungen, Berlin, 1809.

‡ I allude to the winter of 1816–17, which I spent at Edinburgh. In 1819 I visited Auvergne, and published a short account of my observations in Jameson's Journal, vols. iii. and iv. In the same year the first notice of Beudant's researches in Hungary appeared in Daubuisson's 'Traité de Géognosie.' They were three years afterwards more fully detailed in his own work, entitled 'Voyage en Hongrie,' from which I have drawn a great part of my account of the structure of the volcanic rocks of that country. In 1820 Professor Buckland examined the Vicentin, and satisfied himself with respect to the analogy which the strata in that country seen alternating with volcanic products bear to the beds above the chalk in England. He also visited Auvergne and part of Hungary. Mr. Bakewell likewise has noticed Auvergne in his 'Travels in the Tarentaise,' London, 1823. The foreign contributions to the knowledge of volcanos will be seen by reference to my general list of works on the subject. It is to be regretted that the death of Professor Playfair so soon after his return from Italy should have prevented the public from being benefited by his researches in that country.

§ Esmarck, Kurze Beschreibung einer Reise durch Ungarn, 1799.

|| Fichtel, Mineralogische Bemerkungen von den Karpathen, Wien, 1791.

proofs in favour of the igneous origin of trap, as in collecting facts which might tend at once to elucidate the differences subsisting between these two classes of allied phænomena, and to reveal the causes upon which they depended.

Accordingly it was my endeavour to show, by an examination of volcanic rocks of all ages, that the products, whether of ancient or of modern igneous agency, were in all respects such as we might deduce *à priori* from considering the condition of the earth's surface during the several periods at which it was in operation. And although during the period that has elapsed since the first publication of my Treatise, the great body of geological readers have, it is to be presumed, too completely satisfied themselves with respect to the identity of the igneous causes which have been at work formerly and are in existence at present, to require any longer having the facts that confirm that position pressed upon their attention, still it remains open to inquiry, whether the operation of such causes may not once have been more diffused, or more energetic than at present, and whether periodical exhibitions of convulsive energy may not have alternated with the slow and gradual working of the forces which develope themselves before our eyes.

So long as this controversy continues, the phænomena of volcanos will present an interest even independent of that which they must ever command from their own imposing nature and their present influence upon the structure of the globe, thus creating that demand for a full and comprehensive survey of their various effects, divested of theory, and got up with no view to the inculcation of any peculiar theoretical opinions, which may explain the call that has been made for the republication of this Treatise at various times since the first impression of it was exhausted, but to which a variety of engagements, of a nature more pressing and more immediately connected with the routine of my official duties, has until now prevented me from responding.

CHAPTER II.

General nature of Volcanic action.—Volcanos, how distinguished from other phænomena presenting some of the same external appearances.—Phænomena attributable to Volcanic action.—1. Lava Streams and Ejections of Cellular materials.—2. Form and Structure of the Mountains in which they appear.—3. Mechanical and Chemical condition of the individual Rocks.—Glassy and Cellular texture.—Chemical constitution considered.—Felspar the result of Igneous causes.—Mode of distinguishing the nature of the component parts in Volcanic products.—Varieties of Felspar considered.—Difference between Granite and Trachyte.—Varieties of Trachyte considered.—Gradual increase of Bases in other volcanic products, giving rise to the several kinds of Lavas and of Trappean Rocks.—Classification of Volcanic products under two great divisions.—Olivine—Leucitic porphyry—Hypersthene rock, &c. noticed.

General Nature of Volcanic Action.

If we contemplate a volcano whilst in a state of vigorous action, the phænomena presented to us are at once so peculiar and so impressive, that it would seem unnecessary to be at the trouble of defining that which the commonest observer could hardly fail to recognise again, after having once witnessed it in operation.

The evolution of steam and ignited matter from an orifice in the earth, generally situated on the summit or flanks of a conical mountain; the ejection of fragments and scoriæ, bearing a near resemblance in their condition and aspect to the slag of an iron-foundry; the sudden and copious extrication of elastic fluids, with their natural concomitants, noise, and a concussion of the rocks through which they force their way,—are circumstances which strikingly impress upon the imagination the paroxysms of volcanic action, and appear to distinguish this from all the other operations of nature.

Accordingly, from the earliest periods the existence of volcanos had excited attention, and their leading phænomena were pretty correctly described,—they have supplied a groundwork for the superstitions of the vulgar and for the

speculations of the philosopher; and much of our present knowledge with regard to the character, extent and date of their operations may be collected from the incidental notices of them transmitted to us by the historians, and even by the poets of antiquity.

Nevertheless, when we examine the subject more attentively, difficulties occur with respect to the real relation borne by them to several of those phænomena which, from some obvious feature of similarity, have been regarded as their offspring.

If, in conformity to the vulgar idea, all *burning* mountains are ranked amongst volcanos, we admit into the same class a variety of incongruous appearances, which possess indeed no one character in common, except that of being accompanied with what seems at least to be an emission of flame, and which are therefore assignable, in all probability, to causes of many different kinds. If, on the contrary, none but such as present this obvious resemblance to existing volcanos are to be included in our definition, we lose the advantage of considering a series of effects evidently allied to the subject before us, and perhaps equally illustrative of its real nature.

How different, for example, are the eruptions of Vesuvius and Etna, in *kind* as well as in *degree*, from the emanations of gas and aqueous vapour which proceed at times from the sulphureous soil at Macaluba in Sicily, from the foot of the Apennines near Modena, and still more remarkably, it is said, in Crim Tartary and in the neighbourhood of the Caspian*; or from the emissions of gas now observed at Pietra Mala between Bologna and Florence, and the spontaneous fire (as it was believed to be) which in ancient times added to the superstitious reverence entertained for the sacred peaks of Parnassus!

On the other hand, if we consider the character of the phænomena exhibited, how intimate is the connection between

* Whether these latter result, as Sir Roderick Murchison in his 'Russia' supposes, from volcanic processes, will be discussed hereafter; in this early stage of the inquiry it is only necessary to remark, that these phænomena are of too anomalous a character to be assumed amongst the *data* upon which to build a theory of volcanic operations.

the eruptions of Vesuvius and the earthquakes or hot springs in its vicinity; and, looking only to the nature and constitution of the mineral products, how impossible is it to draw a line between those which have *evidently* resulted from its eruptions in modern times, and many rocks in the contiguous country, where nothing of a volcanic nature has as yet been noticed as occurring!

Phænomena attributable to Volcanic Action.

In order, therefore, to establish a sufficiently broad basis on which to ground any general conclusions with regard to the agency of this cause throughout nature, it seems necessary to settle, in the first place, what phænomena, independently of those more palpable ones which first occur to the imagination, are to be regarded as indicative of volcanic action, exerted under the same circumstances as at present, though possibly at a very remote period.

It is clear that the date of the eruption which gave rise to these effects will be immaterial to our present purpose, provided we possess an equal certainty as to its reality; and that we shall be entitled to avail ourselves of the evidence to be derived from extinct no less than from existing volcanos, just as the traveller, who should endeavour to collect proofs of the existence of iron-foundries in an unknown country, might be at liberty to infer their presence, not only in places where they were at the time established, but also wherever such accumulations of slag and scoriæ were found as could only have arisen from the same formerly in operation.

Now the circumstances which may be held sufficient to substantiate the existence of volcanic operations, of a description similar to those at present proceeding, are derived from three sources:—

1. Indications of internal commotion, inferred from heaps of stones and scoriæ that appear to have been ejected; from lava-currents, the course of which from their points of emission to considerable distances may be distinctly traced; and from aqueous vapour, or gases possessing those chemical properties which will be hereafter considered, which are still evolved from this part of the earth's surface.

2. The resemblances in structure borne by the masses taken collectively to that of volcanos now in action, under which head we may rank the existence of a mountain approaching to a conical form, and composed wholly, or at least superficially, of strata possessing what is called a quâquâversal dip, or sloping away in all directions from a common centre, where some vestiges remain of a crater-shaped cavity.

3. The condition of the individual rocks themselves, whether mechanically or chemically considered. Their mechanical condition supplies the most obvious and conclusive evidence, namely a texture approaching more or less to that of glass, together with a structure, partially at least, honeycombed with cells and cavities. Both these peculiarities obviously result from a state of fusion, coupled with an evolution of elastic vapours having taken place during the period of cooling. But their chemical constitution affords indications of even more importance, as it extends to all rocks comprehended under the same category, whilst the mechanical characters alluded to are only partially present.

It would indeed be too much to say, that all igneous rocks possess an analogous chemical composition ; for there are interspersed, even through formations of a decidedly volcanic origin, masses of many different kinds, to say nothing of the numerous imbedded minerals that occur in the greater number of such rocks.

But it may be fairly laid down, that a mineral analogous to felspar, in chemical composition at least, if not in mineralogical characters, constitutes the basis of every true volcanic formation, and that the apparent impossibility, without the aid of heat, of reducing its principal ingredients to such a state of liquidity as seems essential to any chemical union taking place between them, constitutes in itself a strong presumption that those rocks, which, like granite, consist mainly of it, have been produced by the operation of fire.

But how, it may be asked, can we be justified in applying this test as an indication of igneous action in general, when the very operation of the heat may be expected, as in our artificial processes, to obliterate all distinctions of mineralogical character, and thus only to produce felspar in the rare

accident in which its several constituents were presented to each other exactly in the proportions which would form it? And accordingly it is notorious that the homogeneous aspect, not merely of vitreous lavas, but even of trap rocks in general, and particularly of basalt, is such as to baffle all attempts which can be made by simple inspection to determine the mineral constitution of the mass.

To this we may reply, that heat affects a mineral in two ways, according to the rate at which the subsequent cooling is allowed to proceed.

When the latter takes place rapidly, all traces, not only of crystallization, but even of segregation of parts will be obliterated, and the entire mass will assume throughout a uniform texture, like that of glass.

In such an instance as this, however, we do not require any such test as the one proposed, because the vitreous character which the whole presents sufficiently reveals its igneous origin.

But in the case of those substances which have returned more slowly into a solid state, and which in consequence have acquired a stony aspect, there appears to be always an exertion of the chemical affinities subsisting between the several constituents of the mass, sufficient to cause the production of distinct minerals, even when the latter are so intimately blended as to present a uniform appearance to the eye.

Now here, two methods have been suggested for the purpose of determining the nature of the minerals so confounded.

The first is that adopted by M. Cordier, but, so far as I know, not much practised by any other mineralogist. It consists of a careful process of levigation and washing, by which the several minerals composing a trappean rock should be separated by their specific gravity; somewhat on the same principle in which tin and other metals are abstracted mechanically from the earthy impurities that accompany them*.

But a more easily applicable method of discrimination has been pointed out to us by Professor Gmelin, who ascertained

* Cordier sur les Substances Minérales dites en masse, Journ. de Phys. vols. lxxxii. lxxxiii.

that many trappean rocks of homogeneous texture, such as clinkstone and basalt, are separable into two portions by *digestion in muriatic acid,* which dissolves one part and leaves the other untouched.

This separation being effected, it is easy afterwards to determine, by chemical analysis, the mineral constitution of the respective parts.

By this method it has been discovered that clinkstone is an intimate mixture of felspar and of a zeolite; and dolerite, of which the majority of lavas consist, of labradorite (which, as we shall see, is a species of felspar) intermixed with augite. Basalt indeed is by the same method found to be composed of a zeolite, of augite, and of magnetic iron; but then the resemblance in composition between the zeolitic mineral and one species of felspar, namely labradorite, the presence of water being the chief difference between the two, leads to the suspicion that the basis of this rock likewise is of a felspathic nature.

Since felspar then is an ingredient in most rocks of igneous formation, it is important to obtain in the first instance a clear notion of its chemical nature, and of its relations to other bodies.

It is to be regarded, in the first place, not as a single mineral, but as a generic name for several different ones, possessing certain characters in common, as well as an analogy in respect to their chemical constitution.

We may define it as indicating a mineral, the primary form of which is an oblique rhombic prism, whilst its chemical composition is that of two silicates united together; the first consisting of silica united with any base which contains only one atom of oxygen, the second one where that body is united to a base in which the proportion of oxygen to the radical is as three to two.

But this definition gives scope for a considerable diversity of chemical composition, since silica is capable of entering into chemical union with bases in the proportion of one, two, and three atoms; and accordingly I may enumerate the following species of the felspar family, as distinguished by Rose and his disciples. In this enumeration however I will endea-

vour to simplify the matter as much as possible, by pointing out, in the first place, merely the relation which the silica bears to the base which contains three atoms of oxygen to two of radical; and in order to avoid an inconvenient circumlocution, will speak of this base as though it were *in all cases* alumina, that being the negative element possessing the above composition which is most commonly found in union with silica in this class of minerals.

In anorthite, then, and in labradorite, the silica is to the alumina in the proportion of atom to atom, the difference between these two minerals consisting in the former being composed of three proportionals of this combination, in the latter of only one.

In the andesin, or the felspar from the Andes, as well as in oligoclase, the silica is to the alumina in the proportion of two to one; the difference between them consisting in the proportion which the silica bears to the base with one atom of oxygen.

Lastly, in pericline, albite, glassy felspar, adularia, and orthoclase, the proportion of silica to alumina is as three to one, the largest amount in which it is capable of entering into chemical union with any base whatsoever.

The chemical differences between these four minerals consist in the nature of the base with one atom of oxygen united to silica, which they contain; this in orthoclase is chiefly potass; in albite wholly soda; in pericline partly potass, but chiefly soda; and in adularia chiefly potass, though a small amount of soda is also present.

Thus we have in the felspar family three several gradations in the proportion which the silica bears to the alumina combined with it, namely, one, two, and three atoms to one of base, as may be seen by the following table, for which I am indebted to Abich.

Tabular View of the Chemical Constitution, Specific Gravity, &c., of the Mineral Species comprehended in the Felspar Family.

Name.	Locality.	Specific Gravity.	Principal Constituents.					Formula.
			Silica.	*Alumina.*	*Lime.*	*Potass.*	*Soda.*	
1. Anorthite .	Monte Somma	2·7630	43·79	35·49	18·93	0·54	0·68	$\dot{R}\,\dddot{Si} + 3\,\underline{\dddot{R}}\,\dddot{Si}$
2. Labradorite	Mount Etna ..	2·7140	53·48	26·46	9·49	0·22	4·10	$\dot{R}\,\dddot{Si} + \underline{\dddot{R}}\,\dddot{Si}$
3. Andesin ..	Popayan, Andes	2·7328	59·60	24·28	5·77	1·08	6·53	$\dot{R}^3\,\dddot{Si}^2 + \underline{\dddot{R}}\,\dddot{Si}^2$
4. Oligoclase	....	2·6680	62·61	24·11	2·74	0·75	8·89	$\dot{R}\,\dddot{Si} + \underline{\dddot{R}}\,\dddot{Si}^2$
5. Pericline ..	Pantellaria	2·6410	67·94	18·93	0·15	2·41	9·98	
			68·23	18·30	1·26	2·53	7·99	
6. Potass-albite ..	Drachenfels ..	2·6223	70·22	17·29	2·09	3·71	5·62	$\dot{R}\,\dddot{Si} + \underline{\dddot{R}}\,\dddot{Si}^3$ (5–7)
7. Albite	....	2·6140	69·36	19·26	0·46	?	10·50	
8. Ryacolite .	Monte Somma	2·6180	50·31	29·44	1·07	5·92	10·56	$\dot{R}\,\dddot{Si} + \underline{\dddot{R}}\,\dddot{Si}$
9. Glassy (or Soda) Felspar	Ischia	2·5970	66·73	17·56	1·23	8·27	4·10	
10. Adularia ..	St. Gothard ..	2·5756	65·59	17·97	1·34	13·99	1·01	$\dot{R}\,\dddot{Si} + \underline{\dddot{R}}\,\dddot{Si}^3$ (9–12)
11. Orthoclase	Baveno	2·5552	65·72	18·57	0·34	14·02	1·25	
12. Artificial Felspar ..	Made at Sangershausen	2·5600	65·03	16·84	0·34	15·26	0·65	

The minute quantities of the peroxides of iron and of manganese, of titanic acid and of magnesia, are not stated.

N.B. The first seven species belong to the *ein und eingliedriges Krystall-system* of Weiss, or the *anorthotype* one of Mohs, the axes of crystallization being unequal, and not mutually related; whereas the last five species belong to the *zwei und eingliedriges* System of the former, and the *hemiorthotype* of the latter, two of the unequal axes bearing a certain relation to each other, so as to constitute a pair.

It is observable that in these instances, as well as in most others, in which the products of igneous action are concerned, the specific gravity of the mineral is inversely as the amount of silica, and directly as that of the other bases, so that a near approximation may be often obtained to their chemical composition by merely ascertaining their weight.

This accordingly is the method proposed by Abich, in order that we may appreciate the real mineralogical composition of a rock, in which the component parts are so blended together that it is impossible to separate one from the other for the purpose of examination.

In such cases, supposing iron and other of the heavier metals not to be present in quantity sufficient to affect the

result, the specific gravity will often give the proportion of silica, and from the proportion of silica the nature of the felspathic mineral present may be in general estimated with sufficient precision*.

Now it is important to observe, that the kinds of felspar commonly found in granite are those which contain the largest proportion of silica, namely, either orthoclase, adularia, or albite. Where, as is often the case, orthoclase and albite are both present, the basis is generally composed of the latter, whilst the imbedded crystals consist of the former.

Such is the case at Carlsbad, and this fact affords perhaps the true solution of a question which I started in my Report on Mineral Waters (British Association Reports, vol. v. 1836, p. 24), namely, why this and other thermal springs which issue from granitic chains, hold in solution carbonate of soda, but not carbonate of potass, the greater compactness of the crystals interfering with their solubility.

Now, by considering the nature of its felspathic material, it being one of those varieties of that mineral in which the silica is in the proportion of three atoms to only one of base, we may see the reason why in granite a certain proportion of quartz, or uncombined silica, is almost universally present.

Its amount in fact represents the excess of silica existing in the rock over and above that which could combine with the alumina, and hence it implies, that at the time and at

* Thus,

			per cent.
Trachytic porphyry having a sp. gr. of	2·5783	contains of silex	69·46
Trachyte	2·6821	"	65·85
Domite	2·6334	"	65·50
†Clinkstone	2·5770	"	57·66
Andesite	2·7032	"	64·45
†Glassy Andesite	2·5851	"	66·55
Trachyte-dolerite	2·7812	"	57·66
Dolerite	2·8613	"	53·09

The only exceptions being clinkstone and glassy andesite marked †, the former having the same composition as trachyte-dolerite, but an inferior specific gravity; the latter corresponding nearly with clinkstone in both these particulars. It is to be remarked, however, that clinkstone, although chemically resembling trachyte dolerite, has a different mineral composition, for it appears to be a mixture of a zeolitic mineral with glassy felspar. Probably the same may apply to glassy andesite.

the place where the granite was formed, there was not a sufficient quantity present of the several bases to combine with the whole of the silicic acid.

And if we examine the composition of the various rocks which have been produced by the operation of volcanic forces in ancient and in modern times, we shall be able to trace a gradual scale of diminution in the proportion of silica and a corresponding increase in that of the bases present.

The first great division of them is comprehended under the name of Trachyte, a generic term for a class of rocks of igneous formation, characterized mineralogically by their harsh and gritty feel, together with the frequent presence of crystals of glassy felspar, and chemically as being trisilicates, with or without an excess of silica.

They are divided by Abich, who follows, in a great degree, the classification of Beudant, into—

1. Trachytic porphyry, in which quartz is present, but neither hornblende, augite, nor titaniferous iron appears. It is found not only in Hungary, but also in the Ponza, and in some of the Lipari islands.

2. Trachyte properly so called, in which no quartz occurs, but which contains crystals of hornblende and even of augite, together with mica.

3. Andesite, the trachytic rock of the Andes, described by Abich as being of various degrees of compactness and consistency, possessing a coarse conchoidal fracture, and containing a large number of small white crystals, resembling albite, in a crystalline base of a darkish colour. Small crystals of glassy felspar occur, though rarely, in this variety of trachyte, but those of hornblende are very common, and augite is also present. It sometimes passes, through the predominance of hornblende, into greenstone or diorite.

Thus the rock composing the summit of Chimboraço, which has a basis resembling pitchstone, and which is destitute of hornblende, though rich in augite, is called by Von Buch an andesite. Antisana also, and Cotopaxi are said to consist of the same, and it is probable that this rock, in connection with trachyte properly so called, constitutes the greater part of those volcanic mountains in South America which are destitute of craters.

4. Obsidian and pumice, which are so connected, both physically and mineralogically, that they must be placed under the same head, and regarded merely as expressions for two different conditions which the same original material has been made to assume by the agency of volcanic forces. Both indeed have been regarded rather as particular states which many different minerals are capable of assuming, than as distinct species; but it is to be remarked, that simple silicates and bisilicates of alumina are incapable of assuming either a vitreous condition such as that of obsidian, or those cellular and filamentous forms which we observe in the different varieties of pumice.

It is necessary therefore that the rock should be rich in silica, or be a trisilicate; and hence, if with Abich we divide pumices into two groups, namely into cellular and filamentous, the former being dark green, poorer in silica, and richer in alumina—the latter white, and containing more silica, we shall find that the former is derived from clinkstone, trachyte, and andesite, and the latter from trachytic porphyry.

5. Pearlstone, a rock frequent in Hungary, and characterized by the presence of crystallites, or little globular concretions more or less vitreous, and generally scaly, with a pearly lustre arising from the commencement of a kind of crystallization in the mass; or where this is wanting, passing either into a stony condition, or into a semivitreous one corresponding with that of pitchstone, with which latter mineral it seems to be nearly allied.

6. Trachytic tuff, the principal rock covering the Phlegrean fields, the analysis of which proves that, like pumice, it is only a metamorphosed condition of trachyte. Thus tuff, pumice, and obsidian are all modifications of the same volcanic basis; and the two former contain water chemically combined: namely, yellow tuff, three atoms; white tuff, two atoms; pumice, one.

Now lava, although commonly accompanied at the time of its eruption by abundance of steam, and containing, even for several months afterwards*, entangled within it, a large quantity of this and other volatile matters, holds no water in che-

* See my Memoir on the Eruption of 1834, in Phil. Trans. for 1835.

mical combination, so that the fact stated with respect to tuff and pumice shows, that these formations have been placed under circumstances of another kind from those of modern lavas.

We must therefore regard the two former as caused by water operating in a different manner from the steam which accompanies a flow of lava, inasmuch as the latter never contains any of this principle in a state of actual combination.

All these varieties then of volcanic products, which Abich has classed under the general name of Trachyte, approximate to granite in the circumstance of containing a trisilicate of alumina or of some corresponding base, and hence may be supposed to be more immediately derived from the latter rock, than other igneous formations are. Nevertheless in one variety of it, namely in the species distinguished by Beudant as trachytic porphyry, quartz is present, and accordingly this modification would seem to present the nearest approximation to granite, the chief difference indeed between the two being the partial substitution of glassy felspar for orthoclase, minerals of analogous constitution, though possessing different external characters, and with different relative proportions of the two alkalies present in them.

In trachytes, properly so called, there would appear to have been such an accession of alkali and of earths, that the whole of the silica entered into combination, for which reason no quartz exists in the rock.

But when we proceed to the lava-currents which have been emitted from actual volcanos, or to the analogous trap formations which are regarded as the effects of submarine eruptions, we find a still further diminution in the proportion of silica, indicated by the substitution of labradorite for orthoclase, or, in other words, of one atom of silica instead of three, coupled with the presence of hornblende or augite*, in

* Hornblende is $\dot{R}\ \dddot{Si} + \dot{R}^3\ \dddot{Si}^2$, where $\dot{R}$ is generally lime, but sometimes protoxide of iron or soda; and $\dot{R}^3$ is generally magnesia, but sometimes protoxide of iron. In some hornblendes the silica seems to be partially replaced by alumina.—*Bonsdorff*. Augite is $\dot{R}^3\ Si^2$, where $\dot{R}$ is either lime, magnesia, protoxide of iron, or protoxide of magnesia. The silica is sometimes replaced by alumina, as is the case also in hornblende. See *Rammelsberg's Dictionary of Mineralogy*, Berlin, 1841.

both which minerals the silica bears a still smaller proportion to the base with which it is combined.

In these last minerals two new elements also make their appearance, which are seldom or never present in granite or in trachyte, except in small quantities—I mean lime and magnesia; thus evincing already a change either in the nature of the igneous operations, or in the materials upon which they were exerted.

Accordingly the modern lavas of Mount Etna have been determined by Rose* to consist of an intimate mixture of labradorite and of augite, and a lava which had recently flowed from Stromboli was ascertained by Abich to possess the same composition.

Augite rock, or dolerite, is composed of nearly the same materials, its compactness being merely the effect of the greater pressure to which it was subjected during the act of cooling.

Abich, however, has found it necessary to distinguish a class of formations intermediate between trachytes and dolerites, which he denominates trachyte-dolerite. To this he refers the rocks which encircle the peak of Teneriffe, those of one of the volcanos in Kamtschatka, the constituents of the little cluster of islands between Lipari and Stromboli described by Hoffmann, and above all the material which constitutes the Monte della Croce, the central cone of Rocca Monfina, an extinct volcano in the Neapolitan territory. Abich considers the felspar present in this rock to be oligoclase, which by reference to the table will be found to be a bisilicate, and the many green specks of augite which pervade it indicate a further change in the composition of the mass, and a nearer approach to dolerite. With this latter material, which, as we have seen, in general implies a compound of augite with one of those species of felspar which are poorest in silica, the rock called basalt must not be confounded; as in it we may recognise a still further step in the elaboration of the constituents, this substance being composed of an intimate mixture of augite and magnetic iron with a mineral of the zeolitic family. The composition of the latter is such as to imply that it may have been formed

* Phil. Journ. vol. xxiv. 1838.

out of labradorite by the addition of water, the presence of which in all *zeolites* is the cause of that bubbling-up under the blowpipe, which has occasioned them to be distinguished by that general appellation.

We perceive a similar change in the rock called *clinkstone*, which has been shown by Gmelin to be an intimate mixture of glassy felspar with a zeolite, so that it seems to bear the same relation to trachyte which basalt does to dolerite.

In proceeding then onwards towards the more modern groups of volcanic formations, we find new ingredients successively coming into play; first the alkalies increasing, then lime and magnesia becoming part of the constitution of the mineral mass, and lastly, water entering into combination with the earthy materials.

The gradual increase of soda is likewise a remarkable circumstance, modern lavas appearing to contain a much larger quantity of it than the volcanic products of ancient periods, and various minerals being hence produced in which this alkali is predominant*.

From the above considerations it would seem to follow, that volcanic products are referable, for the most part, to one of two divisions.

The first will include those which consist principally of one or other of those species of felspar that have been above described, in which the bases exist either as bisilicates or as trisilicates. Such products are placed, in general language, under the head of Trachytes, although, when we wish to specify their exact constitution, we denote them as andesite, domite, trachytic porphyry, pearlstone, and the like.

The second great division comprehends those rocks in which the felspathic ingredient has either itself undergone some further change by the action of heat, as in basalt, where a zeolitic mineral is substituted, chiefly, as it would seem, by the superaddition of water to the pre-existing elements; or where, though the felspar remains, yet it is so intermixed with other minerals, that the external characters of the resulting rock are altogether changed. The mineral most abundant in this class of products is augite; hornblende being also

* As natrolite, nepheline, thomsonite, &c.

found, but being less abundant than in granitic rocks where augite is rare.

The term *greenstone* is often applied indiscriminately to rocks composed of an intermixture of felspar with either of the above two minerals, but in strictness it should be regarded as synonymous with the *diorite* of Brongniart, which is made up of felspar and hornblende.

Rose, however, is of opinion that augite and hornblende are isomeric bodies, the crystalline form being in their case determined by the more or less rapid cooling which the ingredients underwent, so that the presence of the one or the other seems to depend more upon the conditions under which fusion took place, than upon any diversity of original composition. It is evident that in proportion as augite and other associated minerals predominate, the mass will assume various shades of colour from grey to black. Mr. Scrope accordingly has proposed the term *greystone* to indicate the generality of modern lavas; but inasmuch as lavas are of various shades of colour, the name is not constantly applicable to their external aspect; and seeing that different felspathic materials characterise the lavas from different localities, little seems gained in point of precision by adopting it. Where therefore the use of the ordinary term *lava* might lead to mistake on account of the double sense in which it is employed, referring, as it does, to the mineralogical characters of the mass, as well as to the manner of its emission from the interior of the earth, that of *tephrine*, proposed by Brongniart, would seem preferable.

There are a few other minerals of such common occurrence in volcanic or in trappean rocks, that they deserve to be pointed out, and that at as early a period as possible. One of these is *olivine*, a beautiful olive-green substance, found sometimes disseminated, and sometimes in nests, in the compacter kinds of volcanic products. It seems to result from a predominance of magnesia in the rock, for its composition is in general $Mg^3 + Si^2$.

Another, which, where it is found as a constituent of lava, occurs abundantly, is *leucite*, distinguished by its ash-grey colour and regular dodecahedral crystals. These are often so

abundantly disseminated, as to give to the rock containing it the characters of a porphyry, so that the term *leucitic porphyry* is used to designate this particular kind of volcanic product, the presence of which seems to be connected with an excess of potass in the rock, its probable composition being

$$\dot{K}^3\,\dddot{Si}^2 + 3\,\underline{\dddot{Al}}\,Si^2.$$

Another mineral which characterises many trap rocks is *hypersthene*, which according to Rose is a species of augite in which magnesia is generally abundant.

These however and others will be better treated of when we consider the localities in which they abound; and I shall now proceed to a description of the several districts in which manifestations of igneous action most remarkably occur, beginning with those in Central France, as being amongst the best known, in consequence of their easy accessibility from all parts of Europe, as well as the most instructive, from the varied character of the appearances which they exhibit.

CHAPTER III.

ON THE VOLCANOS OF FRANCE.

Central France.—In Auvergne two classes, ancient and modern, distinguished—their characters.—A few of them particularized, viz. Volvic—Puy de Côme—Lake Aidat—Puy Pariou—Puy Graveneire.—Antiquity of the most modern of these considered.—Passage in Sidonius Apollinaris discussed.—Trachytic cones near Clermont—their formation considered.—Ancient volcanic rocks near Clermont—instances of those of an intermediate age.—Lava of Chaluzet—Montaudoux—Gergovia—Puy Charade—Puy Marman.—Tufaceous knolls near Clermont.—Volcanic rocks of Mont Dor—their general character.—Basaltic and Trachytic formations considered.—Alum-rock of Mont Dor.—Age of the volcanic rocks in that district, and the probable mode in which they have been brought into their present position.—Volcanic rocks of Cantal—its Trachyte—Basalt—Clinkstone—its age and the mode of its formation.—Volcanic rocks near Puy en Velay—their antiquity—those in the Haut Vivarais ancient—in the Bas Vivarais modern.—Instances of modern Lavas—Aizat—Montpezat—question as to their eruptions having occurred within the historical period.—Volcanic rocks in the south of France—that of Beaulieu near Aix.—St. Loup near Agde.

The volcanic district, to which my attention was originally directed, in the hope of obtaining some additional insight into the nature and origin of basalt, was that which occupies a considerable tract in the centre of France, known under the general term of Auvergne. This, and some other parts of the same country, also of a volcanic nature, were visited by me in the year 1819, and some of the results of my observations were inserted in the Edinburgh Journal of Science for the ensuing year. In the course of the summer of 1823, I also spent a few days in the same region, and cleared up two or three points which on my former visit had been left undecided.

In the Letters to Professor Jameson above referred to, I distinguished these rocks into two classes—the one formed before, the latter since the valleys of the country were exca-

vated; and in order to keep constantly in view a distinction which I then considered, as I still deem it, of importance, proposed to apply the term *ante-diluvial* to the one, and *post-diluvial* to the other.

This nomenclature appeared to me at the time convenient, although I even then disclaimed all intention of identifying the cause to which the excavation of valleys, and the formation of beds of gravel, were to be referred, with the Deluge recorded in the Mosaic history.

I regarded the terms as admissible, although employed with the same sort of mental reservation with which many geologists had been in the habit of using the corresponding ones of *diluvial* deposits, *diluvial* gravel, &c.—namely, as expressive merely of their belief that they were produced during, or in consequence of, certain transient and violent convulsions, rather than by the continual operation of rains and torrents, acting with their present force and intensity. And I made choice of the terms *ante-* and *post-diluvial* as serving to distinguish the relative antiquity of the rocks so classified with somewhat greater precision than those of *ancient* and *modern* which others had adopted, inasmuch as they referred to a definite standard, which left no doubt in the mind as to the sense in which we employed the word *antiquity* in our geological language.

Without some such understanding indeed, the volcanic rocks near Clermont might be called *ancient* with reference to those of the Vivarais, though they are *modern* when compared with others in their own neighbourhood; whilst in either point of view they must be regarded as *post-diluvial,* since their relation to the valleys of the country is such as to prove that no great changes have taken place in the configuration of the surface since they were ejected.

For these reasons I felt reluctant to abandon my original nomenclature, even after I had become so far a convert to the views of Mr. Scrope, and Messrs. Lyell and Murchison, as to admit that there was in reality no marked line of distinction laid down by nature between these two classes of volcanic rocks*, but that there were lava-currents in Au-

* See article GEOLOGY in the Encyclop. Metrop.

vergne which appeared to be antecedent to some of the valleys of the country, and posterior to others.

Now however that the term *diluvial* seems tacitly given up even by those who still stand out for the theory of paroxysmal eruptions, it is not for me to stickle for the continued use of a nomenclature, which under such circumstances might lead to misconception; and I shall therefore adopt the terms *ancient* and *modern*, as distinguishing volcanic products cut through by the principal existing valleys, from those which follow their actual slope, conceiving, from my recollections of the country, as well as from the admissions of others, that whatever opinion may be entertained as to these two kinds—however probable it may appear, that the oldest as well as the most recent have been acted upon in the same manner, still, that in the great majority of cases, the vast difference in degree, or the longer duration of the process in the one instance than in the other, constitutes in practice a sufficient ground of demarcation.

Modern Volcanic Rocks.

Now the importance of distinguishing the relative ages of these volcanic rocks, in the manner above proposed, will be evident from considering that the two classes differ one from the other in aspect and structure as well as in position.

The modern ones in Auvergne are more cellular, and have in general a harsher feel, with more of a vitreous aspect, their surface presenting a series of minute elevations and depressions, and the scanty portion of soil which covers them affording but little pasturage, and that generally of the worst description.

The mountains referred to this division constitute a chain which rises considerably above the elevated granitic platform on which they rest, and extends at intervals over a space of above eight leagues from north to south; from whence the rocks which compose them may often be traced a considerable way into the valleys contiguous. Above sixty of these eminences might, I believe, be enumerated within the boundary marked out; but as their number renders selection necessary, I shall simply notice such as are most remarkable, beginning with that of Volvic near Riom, the lava of which

furnishes a considerable part of the building-stone used in that neighbourhood, and in spite of its porous character, is exceedingly durable.

The fact of its having descended in a liquid form from the mountain above, and that at a period subsequent to all the great revolutions which have changed this portion of the face of our planet, is demonstrated by the exactness with which the stream has modelled its course to the slope of the valley; and that its fluidity was owing to heat, is evident enough from its porous texture and semi-vitreous aspect; so that its connection with volcanos now in activity seems sufficiently apparent. On the summit of the Puy de Nugere is a bason-shaped cavity of an oblong form, broken away on the side down which the lava has taken its course, and, notwithstanding the changes which time has effected in its form, still retaining marks of having been once the crater from whence the lava of Volvic was ejected.

It is interesting to remark, that the stream in its descent appears to have been arrested by a sort of knoll of granite, which probably rose considerably above the general level, and by the obstacle it opposed to its progress, caused it to divide into two branches, between which this little granitic eminence is seen protruding,—a solitary vestige of the rock which formerly existed on the surface, but which is now overspread with lava. The two branches of the main stream appear to have become re-united below, and having descended the slope of the hill, to have spread themselves over the valley of Volvic, extending to within a mile of the town of Riom.

It has been remarked by Von Buch, that the lava of Volvic seems chiefly to have consisted of felspar, and to have resulted from the fusion of some trachytic rock; and it is certain that it is lighter in colour than most other lavas, and that it does not contain augite. It is also distinguished by exerting no action upon the needle, containing little or no magnetic iron ore; but, on the other hand, it is quite full of *specular iron*, which occurs in the crevices of the rock, as well as disseminated through its porous structure in minute plates of a bright metallic lustre. This mineral, which is a common product of volcanos now in activity, from which it is supposed to have been sublimed, is met with in various other parts of

Auvergne, as at the Puy de la Vache, the Puy de Dôme, and among the trachytes of Mont Dor.

Still more interesting, from the changes it has produced in the configuration of the country, is the lava of the Puy de Côme, a mountain a few miles to the south-west of Clermont, originally described by the Comte de Montlosier, the well-known author of an ingenious Essay on the Theory of the Volcanos of Auvergne, published quite at the commencement of the present century.

The lava that has flowed from the hill above-mentioned, divides, he says, into two branches, one of which flows directly into the bed of the river Sioule, whilst the other takes the direction of a place called Tournebise, reaches the village of Pont Gibaud, and terminates like the other, by flowing into the bed of the river, about three miles lower down.

A torrent of this description might naturally be expected to effect singular changes in the face of the country which it traverses. Accordingly we shall find that it has blocked up a little valley which formerly seems to have had a drainage to the west, on the side of Chambois and Masayes, and has converted it into a sort of swamp, known by the name of the Lac de Côme.

Lower down, the same lava has occasioned still greater changes. The rivers Sioule and Monges formerly ran parallel, in a direction from south to north, and entered the plain of Pont Gibaud by two defiles, separated by the intervention of a line of hills. But one branch of the lava of Côme has so obstructed the course of the river Sioule, that its waters have been turned aside to the left, where they have worked themselves a passage through an argillaceous hill, made enormous excavations in it, and in this manner have reached the bed of the river Monges, a league and a half higher up than they would naturally have done.

Compelled however to flow in a direction contrary to the slope of the country, a large portion of the waters constantly stagnates in its channel, and has formed a swamp which goes by the name of the 'Etang de Fung *,' whilst a portion

* This is very well laid down in Desmarest's Map of Auvergne. Paris, 1823.

only of the stream continues to flow onwards by its original outlet.

Now the changes here brought about in the physical condition of the country through the agency of lava-streams, which, according to the definition I have above given, would be regarded as modern, afford some of the most instructive lessons that can be set before us, how impracticable is the attempt to tie down the operations of nature within the hard lines of our artificial classifications.

We see presented to us in this locality instances of a lava which proceeded from a volcano of apparently modern date, its crater being still entire, and its course being through a valley antecedently filled up, at least in part, with alluvial matter *.

Nevertheless this current, by obstructing the course of a stream, has caused the latter to work its way subsequently through a mass of alluvium no less than 140 feet in thickness, and even through twelve feet of the subjacent gneiss, thus forming a sinuous valley of about two miles and a half in length.

Moreover, the river Sioule has in another place cut for itself a channel through the obstructing bed of lava, which consequently exhibits a perpendicular escarpment near the town of Pont Gibaud nearly fifty feet in depth.

Such facts as these have been seized upon as proofs, that valleys in general may be produced by existing rivers, and that there is consequently no natural line of distinction between *post-diluvial* and *ante-diluvial* volcanos.

Many geologists however are still doubtful as to the forces which would be competent to excavate the so-called valleys of denudation to which reference is here made; and even those who contend for an identity in the mode of operation to which the ravine in which the river actually flows and the ancient valleys of the province owe their existence, must of necessity admit a vast distinction as to time; for what comparison can be instituted between the erosion of 140 feet of soft alluvial matter together with 12 feet of gneiss, or even

* See a Memoir on the Excavation of Valleys, as illustrated by the Volcanic Rocks of Central France, by Mr. Lyell and Sir R. Murchison, Edinb. Phil. Journal, April 1829.

that of 50 feet of lava, and the removal of such vast masses of solid matter as would be required to unite the corresponding flanks of the hills which bound the valleys into which these lava-currents have descended?

It must be remarked too, that the action of the stream has been in these instances accelerated by the soft or unstable character of the subjacent material. When this, for instance, was an alluvial clay, it gave way readily to the pressure of the accumulated waters; and when the basalt rested on a bed of gravel, the stream would cause the fall of perpendicular masses of the igneous rock at frequent intervals, so soon as ever it had worked its way down to the loose materials on which the latter reposed.

Without entering, however, into the wide question relating to the cause of the excavation of valleys, which would carry me far beyond the limits assigned to the present work, I do not conceive that these and other facts of the same kind, of which we have abundant examples in Auvergne, need present any practical difficulty to the adoption of that nomenclature which has been above proposed with the view of separating the volcanic rocks of Auvergne into two classes, although, as in all other cases, the members of the two series may graduate one into the other.

A somewhat similar circumstance to that which has been above noticed with respect to the Etang de Fung has happened in the case of the lake of Aidat, which seems likewise to have been formed originally by the stream of lava now stretching across it. In this case, however, a still greater impediment existing to the escape of the waters by any other outlet, they have in process of time succeeded in cutting themselves channels through the parapet of lava thrown across them, the projecting portions of which stand forth like islands in the midst.

The stream of lava that has occasioned this impediment appears to have been furnished by one of three mountains, all of which have given out *coulées* flowing in the same direction, and therefore intermixed one with the other. The most considerable of these mountains is called the Puy de la Vache, the whole of which is composed of scoriaceous lava very dif-

ferent from that of Volvic, as it contains much iron in the state of magnetic, as well as in that of specular iron ore, the oxidation of which imparts a general redness to the rock, and likewise occasional crystals of augite and olivine. There would seem to have been formerly a crater on the summit, three sides of which are now standing, whilst the fourth was perhaps broken away by the stream of lava which descended from that quarter. The *coulée* is easily followed with the eye along the valley as far as the lake, in consequence of the irregularities of its surface and the ridge which it forms above the level plain.

The most complete crater, however, which exists in Auvergne is that of the Puy Pariou, north of the town of Clermont. It is perfectly round, and, according to M. Ramond, more than 250 feet in depth. Its structure is simple enough, as it consists wholly of loose masses of slaggy lava, sufficiently decomposed to allow of the growth of turf, so that cattle are seen tranquilly grazing within the very spot which once constituted the vent for the pent-up energy of the volcano. It has given off a stream of lava which may be traced southward to the place called "Les Barraques," where, meeting with a projecting knoll of granite capped with ancient lava, it divided into two branches which take different directions, but nevertheless alike descend the slope of the granitic hills intervening between that spot and Clermont, terminating finally near the entrance of the valley in which that city is situated.

But amongst the modern volcanos met with in this neighbourhood, there is probably no one upon the whole more interesting than the Puy Graveneire. This mountain, which lies within two miles of Clermont, seems, as we approach its summit, to consist of an entire mass of scoriform and highly cellular lava, so that we may in some degree comprehend the origin of a ludicrous opinion ascribed to a professor of the Academy of Clermont, when the volcanic nature of the rocks of Auvergne was first asserted, and maintained by an appeal to the structure of this particular mountain, who, it is said, accounted for the scoriæ found on its surface, by gravely remarking that he had heard of iron-foundries having formerly been established on the spot. Notwithstanding such strong

indications of its having been in a state of ignition at a comparatively recent æra, no trace of its crater can be detected, nor has it that abrupt and conical form characteristic of volcanic hills, being rather a long, round-backed eminence, rising abruptly indeed on two of its sides, but to the north connected with the chain of the Puy de Dôme, and to the south reaching into the plain of Limagne. In spite of the absence of a crater, two streams of lava appear to have pierced the sides of this mountain through a bed of ancient basalt, which here caps the granite of the country. They have thence descended into the valley, one on the side of the village of Royat, the other on that of the Puy Montaudoux. These *coulées* display a singular intermixture of compact and cellular lava, the former generally occupying the centre, and surrounded by the latter variety, but without any marked line of demarcation between the two. The compact rock is a basalt, remarkable for its large distinct crystals of augite and olivine; and its being seen in connection with a lava of so cellular and vitreous an aspect affords, in common with the facts I shall detail with respect to the German volcanos, a sufficient proof that great pressure is not always necessary for the formation of such products.

I shall not stop to particularize any larger number of the more recent class of volcanos, as they are much the same in their characters with those already enumerated, and differ very little from such as are at present in activity in other parts of the world. Indeed, even the streams of lava which they have given out are often so little decomposed, so partially covered with vegetation, that we not only readily admit their modern origin, but even imagine they must have been formed within the limits of authentic history.

Nor have we a right to assume an entire extinction of these processes throughout the district; for the frequency of thermal and of acidulated springs—the copious evolution of carbonic acid which takes place, according to M. Fournet, in the mines of Pont Gibaud, as well as in other localities—the springs of bitumen also met with—and the abundant deposition of travertin now taking place near Clermont, where it has stretched across a rivulet, forming a natural bridge

over it *,—cannot but be viewed as indications of a languid action of volcanic forces still continuing underneath.

The records nevertheless of any actual eruptions are nowhere to be found, and the evidence we are in quest of can only, it would seem, be collected from the volume of nature, which in this instance speaks a language so intelligible; for with regard to the popular names of certain of the mountains and valleys †, to which some have referred as indications of a remote tradition, it seems more probable that they were applied to the places they designate, in consequence of the ideas which their appearances were calculated to suggest to the minds of their first inhabitants, than from the latter having been themselves eye-witnesses of the events which occasioned them.

I remarked, indeed, in the former edition of this work, that if any of these volcanos had been in a state of activity in the age of Julius Cæsar, that General, who encamped upon the plains of Auvergne and laid siege to its principal city, could hardly have failed to notice them; and that had there been any record even of their existence in the time of Pliny or Sidonius Apollinaris, the one would scarcely have omitted to make mention of it in his Natural History, nor the other to introduce some allusion to it among his descriptions of this his native province.

The learned author of an article in the Quarterly Review on the Norman Conquest ‡ has questioned the soundness of this inference, and whilst he has erroneously placed me in opposition to Mr. Lyell, who on the contrary in this instance adopts in his work § the very conclusions I had previously arrived at, even cites against me the testimony of Sidonius Apollinaris and of Alcimus Avitus, the Bishop of Vienne, as proving the existence of active volcanos in Auvergne during the fifth century after Christ ‖. But in so doing, the Reviewer seems to me to have confounded together the volcanos of

* The petrifactions produced by this spring are well known and much admired.

† Such are Montbrul, Vallée d'Enfer; and perhaps the very name of the province may be derived from certain appearances that might have reminded its first settlers of the lake *Avernus* near Naples.

‡ Oct. 1844.

§ Principles of Geology, vol. iii. p. 269.

‖ Gregory of Tours has also been mentioned as an authority on the same side, but I can only find that he bears testimony to a great earthquake which shook the city of Auvergne during the episcopate of St. Gall in the sixth century.

Auvergne and those of the Vivarais, two groups, which, although scarcely 100 miles distant from each other, are nevertheless divided by a barrier of primary rocks, and belong apparently to independent systems*.

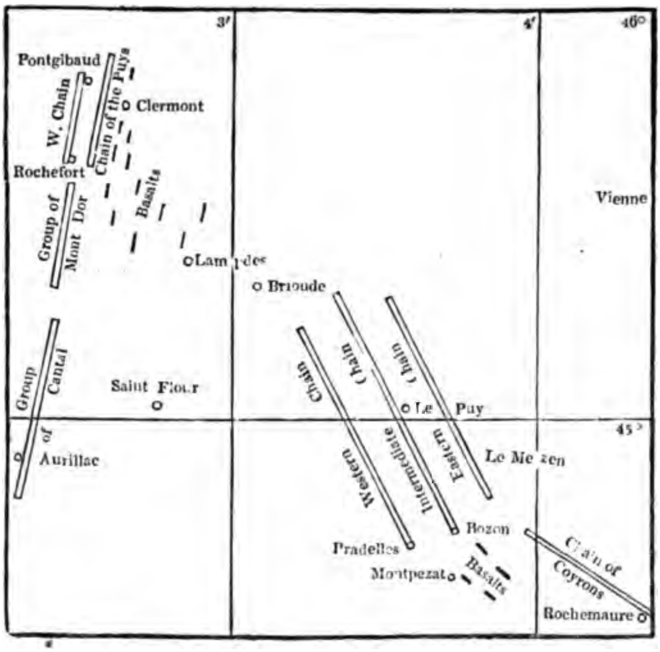
To infer that the volcanos of Auvergne were in a state of activity at the time when those of the Vivarais showed symptoms of disturbance, would be as rash as to presume that the extinct volcano of Mount Vultur in Apulia was roused into activity in the first century of the Christian æra, because ancient writers have recorded the ravages made at that time by Vesuvius.

The letter which Sidonius addresses to the Bishop of Vienne evidently alludes to events which occurred within the diocese and the neighbourhood of the latter, if not immediately around the city in which he resided. "*Non enim latet nostram sciscitationem,*" says Sidonius, "*primis temporibus harumce supplicationum institutarum, civitas cœlitus tibi credita per cujusmodi prodigiorum terriculamenta*

---

* The annexed woodcut may be useful as showing the relative position of the volcanos of Central France to each other and to the city of Vienne.

Relative position of the several Chains of Volcanos in Central France.



vacuabatur. Nam modo, scenæ mœnium publicorum crebris terræ motibus concutiebantur; nunc, ignes sæpe flammati caducas culminum cristas superjecto favillarum monte tumulabant." And as Alcimus Avitus was the successor in the see of Vienne to Mamertus*, to whom Sidonius's epistle was addressed, the allusions which the former Prelate in his Rogation Homily makes to the same fearful catastrophes would seem to refer to this locality rather than to one more distant.

I therefore submit to my readers, whether the entire silence of Sidonius as to the existence of volcanos in Auvergne, although his residence was on the borders of the lake Aidat, which, as we have seen, was caused by an eruption from one of the most modern of those which had desolated the country, is not a strong negative evidence of their antiquity, especially when this author dwells in his poems on the scenery of his own neighbourhood, and even compares its natural beauties with those of Baiæ, a spot which he must have known to be in the neighbourhood of a burning mountain.

How natural would it have been for him, after he had said, with reference to his *Baths* on the lake of Aidat,—

"Æmula Baiano tolluntur culmina cono,
Parque cothurnato vertice fulget apex," &c.†

---

* It may be well to add the extract from Avitus's Rogation Homily to which the reviewer refers:—

"Et quidem terrorum temporis illius causas multos nostrûm recolere scio; siquidem *incendia crebra, terræ motus assidui, nocturni sonitus, cuidam totius orbis funeri prodigiosum quoddam bustuale minitabantur.* Nam populosis hominum concursibus domestica sylvestrium ferarum species observabatur, Deus viderit an ludificans oculis, an adducta portentis. Quicquid tamen ex iis duobus foret, perinde monstruosum intelligebatur, seu sic veraciter immania bestiarum corda mansuefieri, seu tam horribiliter conspectibus territorum falsæ visionis phantasmata posse confingi. Inter hæc diversa vulgi sententia, dispariumque ordinum variæ opiniones. Alii quod sentiebant dissimulando, quæ fletui nolebant dare, casui dabant; alii spiritu salubriore, abominabilia nova quoque congruis malorum proprietatis significationibus interpretabantur. *Quis enim in crebris ignibus, imbres sodomiticos non timeret? Quis trementibus elementis, aut decidua culminum, aut disrupta terrarum imminere non crederet?* Quis videns, certe videre se putans, pavidos naturaliter cervos per angusta portarum usque ad fori lata penetrantes, non imminentem solitudinis sententiam formidaret?"—*Alcimi Aviti Homilia de Rogationibus, Ed. Sirmond.* ii. 90.

† The following are the lines to which reference is made:—

CARMEN XVIII.

De Balneis Villæ suæ supra lacum positæ.

Si quis Avitacum dignaris visere nostrum,
Non tibi displiceat, si quod habes placeat.

to have added, that in its vicinity too, as in that of Baiæ, there was a mountain vomiting forth flames, supposing any such phænomenon to have been familiar to him near the spot where he resided! When therefore, as I remarked in my former edition, Sidonius, under the apprehension of an attack from the Goths, informs the Bishop of Vienne that he is going to enjoin public prayers, similar to those which the bishop had established at the time when "*earthquakes demolished the walls of Vienne, when the mountains opened and vomited forth torrents of inflamed materials, and when the wild beasts, driven from the woods by fire and terror, retired into the towns, where they made great ravages,*" I conceive, that even admitting that he may have afforded some evidence in favour of the modern date of certain of the volcanos in the neighbouring province of the Vivarais, his silence as to anything similar having happened in his own neighbourhood speaks strongly in favour of the antiquity of the latter, and disposes us to assign to them an æra as remote as is consistent with the fact of their posteriority to the formation of the principal valleys of the country. With regard to the silence of the elder Pliny as to the existence of volcanos in Auvergne, although I should not bring it forward as conclusive, yet it cannot but be regarded as an extraordinary circumstance, that in his enumeration of the burning mountains existing in Sicily, in Pamphylia, in Lycia, in Bactria, in Media, in Æthiopia, and in so many other less-known localities, he should have made no mention of those in Auvergne, had their slumbers been at that period interrupted.

On the other hand, Mr. Lyell has shown (Quarterly Journal of the Geological Society, No. 6) that one of the most recent of the lava-currents, that from the Puy de Tartaret, which occupies the bottom of a valley at the lower end of the Lac de Chambon, rests upon an alluvial deposit of red sandy clay containing remains of animals, closely allied indeed to existing species, but with some points of difference, indicating that the mammalian fauna was very distinct as a whole from that now inhabiting Auvergne. And that

---

Æmula Baiano tolluntur culmina cono,
  Parque cothurnato vertice fulget apex.
Garrula Gauranis plus murmuret unda fluentis
  Contigui collis lapsa supercilio.
Lucrinum dives stagnum Campania nollet
  Æquora si nostri cerneret illa lacûs.
Illud puniceis ornatur littus echinis,
  Piscibus in nostris hospes utrumque vides.
Si libet, et placido partiris gaudia corde,
  Quisquis ades, Baias tu facis hic animo.

the current which has issued from the Puy de Tartaret was anterior to the period referred to, appears from the fact that a Roman bridge of such form and construction as continued in use down to the fifth century, but which may be older, is now seen at a place about a mile and a half from this spot. The ancient bridge spans the river Couze in two arches which spring from the lava on both banks, showing that a ravine precisely like that now existing had already been excavated by the river thirteen or fourteen centuries ago.

Trachytic Cones in Auvergne.

Let us now proceed to the consideration of another description of rocks found in the same neighbourhood, the nature and origin of which may appear to be somewhat more problematical and less in harmony with the phænomena of volcanos at present in activity.

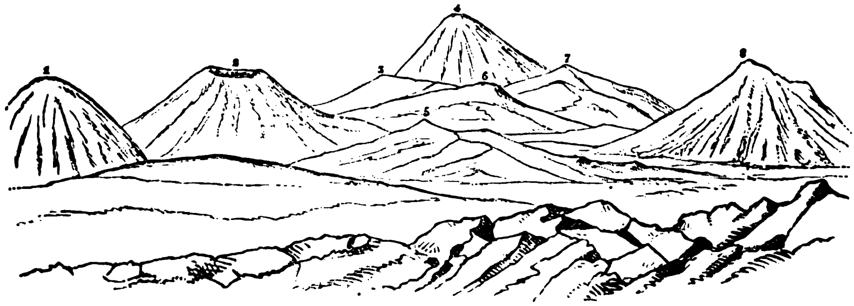
The department of which Clermont is the capital has received its name from a mountain, which as the highest in the province, and occurring in some degree detached from the rest, has acquired more importance than it might in other situations have obtained, although indeed its height is considerable, being 4840 feet. The Puy de Dôme, the hill to which I allude, is of a conical form, and remarkable for the distinctness of its outline, rising abruptly from the midst of a sort of amphitheatre of volcanic rocks, which it considerably overtops, but which, without much stretch of the imagination, might be supposed to have constituted the crater from whence this great central mass was protruded.

However this may be, the mineralogical characters of the mountain are such as differ entirely from those of the hills on either side of it. The Puy de Dôme seems to consist almost entirely of a rock with a felspar base, allied to trachyte, but of a more earthy character, and containing more rarely crystals of glassy felspar. These however do occur even in the most pulverulent part of the rock, and are common in the more compact portions, where indeed the resemblance to trachyte is often so perfect as to leave us in little doubt with respect to the real nature of the rock in general. The term *Domite*, therefore, which was originally assigned to it from its occurring in the Puy de Dôme, must be considered as expressive merely of a variety or subspecies of trachyte, marked

by the earthy character of its basis, and by its whitish or greyish colour. It has disseminated numerous plates of mica, as well as of specular iron, which forms likewise a thin superficial coating on the stone between its crevices, and it contains occasionally quartz, grains of which are sometimes so scattered over it as to give an arenaceous character to the rock.

The most remarkable circumstance relating to this substance is, that it is confined to this hill, and to five others in its immediate vicinity, which, though they all present some modifications of aspect, still possess sufficient of a common character to be referable to the same class. They are all conical, all detached, and have surrounding them hills of a volcanic nature which bear not the slightest analogy to them in appearance. The first three of these, namely the Grand and Petit Cliersou* and the Grand Sarcouy, are composed entirely of domite. The two Cliersous however are covered on the summit by a bed of alluvium two or three feet thick, composed of rounded masses of basalt, granite, felspar, quartz, and pumice. At the Petit Cliersou are likewise found scoriæ and puzzolana. On the other hand, the Grand Sarcouy, which is remarkable for its hemispherical form, truncated on the summit, is destitute of alluvium, although its upper part is strewed over with scoriæ. It is of a looser texture than the rest, and, as has been already observed, is impregnated with muriatic acid.

Trachytic Hills near Clermont in Auvergne seen from the Puy Chopine.



1. Grand Sarcouy.
2. Puy Pariou.
3. Petit Puy de Dôme.
4. Puy de Dôme.
5. Petit Suchet.
6. Cliersou.
7. Grand Suchet.
8. Puy de Côme.

* Also called "Suchet."

The fourth of these is a little hill south of the Puy de Dôme, called the Puy de Gromanaux, of which only one-third part is trachytic, and this apparently a prolongation of the latter mountain. The last in the series is the Puy Chopine, which requires some more particular notice than the rest from the singular confusion and anomalous structure of the rocks which compose it. Owing indeed to the quantity of debris which everywhere covers its sides, where not concealed by vegetation, it is difficult to determine with precision the position they occupy, or the relations they bear to each other. On climbing to its summit, I found, *in situ*, a rock analogous to domite, unaltered granite, and a conglomerate with a granitic base, rocks which seem to be related to each other. Lower down I observed a granular hornblende rock, which appeared to pass into the granite; and these four substances make up, so far as my observations extend, the higher portions of the mountain. Lower down we have lavas, both compact and vesicular, none of which, so far as I observed, occupy the summit, although M. Montlosier, who examined the spot doubtless with more attention, states that he saw one small portion extending thus high. It should be remembered that the Puy Chopine, even more distinctly than the Puy de Dôme, is encircled by an amphitheatre of hills, which are comprehended under the names of the Puy Chaumont and the Montagne des Gouttes. I examined these hills, and found them all to be volcanic, consisting chiefly of a tuff containing portions of scoriæ, and lavas of various denominations, all cemented together by an ochreous paste.

Such, so far as I observed, appears to be the constitution of the Puy Chopine; and the singular assemblage of rocks which it comprises, whilst it serves to explain its own formation, may perhaps furnish us with a clue to the theory of the Puy de Dôme and the other mountains similarly constituted. Encompassed on all sides by volcanic rocks, and bearing in themselves evidences of the agency of fire, the igneous origin of these latter mountains will scarcely be disputed; but the precise manner in which they have been affected by this agent still admits of a question. It may be asked, for instance, whether these rocks are to be considered as separately thrown up like the volcano of Jurullo in Mexico, which will be after-

wards considered, or are the relics of one continuous stratum of felspathic lava. The latter opinion has found an advocate in M. Daubuisson, who seems to consider the Puy de Dôme and its accompanying hills as outliers of the great trachytic formation which extends over the Mont Dor. Von Buch, on the contrary, imagines that the mountains composed of domite have been thrown up from below, elaborated from the materials of the fundamental granite, which had been altered partly by the effect of heat, and partly by elastic vapours.

M. Lecoq, who has written an essay on the origin and constitution of the felspathic Puys of this district, proposes an hypothesis which seems in some measure to combine both the former. He regards domite as formed from a pumiceous conglomerate rock which spreads over much of the older volcanic rocks of Mont Dor, and extends also to Boulade near Issoire in the plain of Limagne. He conceives that this matter, altered by heat, and heaved up in a conical form by elastic vapours, constitutes the domite of the Puys under consideration. This conglomerate he supposes to have formerly overspread the country, but to be in great measure concealed by the volcanic rocks which in more modern times have covered so much of the surface in the neighbourhood of Clermont.

When the volcanic agency was sufficient to burst through this bed of conglomerate, a crater, consisting of scoriæ, cellular lava and the like, would be formed over it; when the force was insufficient, the pumiceous tuff was merely elevated in a conical form above its original site, being likewise acted upon by the joint agency of heat and elastic vapours. Thus the *formation* of the materials composing the Puy de Dôme was contemporaneous with that of the Mont Dor range, but its *elevation* merely dates from the time when the modern lavas around Clermont were erupted. By this theory he accounts for the presence of crystals formed by fire, as well as of pebbles produced by the action of water—for the differences in the constitution of the several hills, arising from the different degrees in which they have been subjected to heat—for their rounded or conical form, the evident result of elevation—and for the general absence, except when there are crystals, of potass, which seems to imply the prior action of water.

The different degrees of elevation may be traced in the several mountains already described; thus at the Puy de Gromanaux, the crater we observe shows that volcanic forces have heaved up the domite, but were not powerful enough to cover it over entirely with ejected materials. At the Puy de Dôme, the two Cliersous and the

Sarcouy, the domite has been merely upheaved without being altered in position, and hence these are still covered by their original bed of alluvium. Lastly, at the Puy Chopine the domite has been upheaved together with the granite on which it reposed.

I present this hypothesis as one emanating from a geologist of some reputation, who has made Auvergne his particular study, although I confess that I do not see the necessity of adopting that part of it which relates to the derivation of the domite from the pumiceous conglomerate of La Boulade. Domite, as I have already stated, is only a variety of trachyte, and as such must be either an altered granitic rock, or formed out of materials similar to those of which granite itself was made up. In what the differences consist, and in what manner they may possibly be explained, will form the subject of a subsequent part of this work, in which the theory of volcanos is made the matter of discussion; at present I need only remark, that the notions which have been thrown out, that the five or six domitic Puys alluded to are the relics of a continuous stratum once overspreading the country, or that they are volcanic cones changed into domite by some unexplained action of heat whilst in their present position, involve so many difficulties, not to say absurdities, as to be scarcely worthy of discussion.

Adopting, therefore, that which is common to Lecoq's and to Von Buch's theory, namely the separate elevation of each of these isolated cones, let us consider how their several appearances may be accounted for on the assumption that domite is formed out of a granitic material altered in some way or other by subterranean heat. In the instance, then, of the Puy Chopine, we may attribute the intermixture of hornblende rock to the circumstance of its forming beds in the granite which was thrown up, whilst the unequal operation of heat may explain the occurrence of the latter substance as well as of the former, unaltered in the midst of domite. With respect to the volcanic trap or lavas which occupy the lower portions of the mountain, we may consider these as detached from the rocks that occur in the Montagne des Gouttes and Puy Chaumont contiguous, elevated, as it would appear, by the same process which thrust up the granite and domite through the midst of them.

The geologist who adopts this view of the subject will regard the modifications of appearance, observable in the rocks which have been referred to the general head of domite, as

arising from some difference, either in the intensity of the heat to which they were severally subjected, or in the mode of its application, rather than in the material from which it was produced.

Thus, M. Montlosier has observed, that the Puy de Monchar, a mountain to the north-west of the Puy de Dôme on the road to Aurillac, seems merely to have been forced up without having experienced any material alteration in structure; for though partly composed of scoriæ and other volcanic products, yet it contains also masses of unaltered granite, unaccompanied indeed, as at the Puy Chopine, with domite, but in such disorder as plainly demonstrates that they do not exist in their natural position.

The second stage of alteration is seen in the case of the Puy Chopine, where the granite is not only raised by some expansive force from the spot it originally occupied, but is also partially converted into the state of domite, whilst a portion still unchanged remains as a specimen of the materials from which the former was produced.

Lastly, in the case of the two Cliersous, the Grand Sarcouy, and the Puy de Dôme, the change from granite into domite is complete throughout, and the whole reduced into a spongy pulverulent mass, as is particularly seen in the Puy Sarcouy. The latter rock still exhales the odour of muriatic acid, and the presence of that substance in it was ascertained by Vauquelin; a fact which will be easily accounted for from the abundant evolution of this acid which takes place from volcanos now in activity.

We have no data on which to fix with any certainty the age of this rock; it is probable indeed that its date is not the same as that of the trachytes of Mont Dor, which will be next considered, since we rarely, if ever, find amongst that extensive formation a substance exactly corresponding to that of which the Puy de Dôme is composed, and the *more modern date* of the neighbouring volcanic products would lead us to infer from analogy that it was less ancient; yet it must be confessed that we want in this instance the direct evidence which is afforded us in the case of those volcanos that have given forth currents of lava.

On the Ancient Volcanic Rocks near Clermont.

I have already admitted, that no decided line of demarcation exists between the class of modern and of ancient volcanic rocks; for here, as in all other cases, though the extremes of a natural series may be as unlike as possible, there will always be certain connecting links which might seem referable almost equally well to either group.

Mr. Scrope, and subsequently Sir Roderick Murchison and Mr. Lyell, have afforded us a striking example of this in their description of the volcano of Chaluzet below Pont Gibaud*, where a stream of lava may be traced from a worn-down crater situated on the western side of a conical hill, called the Puy Rouge, composed entirely of red and black scoriæ, and yet is seen distinctly resting upon a bed of pebbles which separates it from the subjacent gneiss.

The character of the hill from which it issues, the scoriaceous appearance of its own mass, its course in the same direction as that of the valley now existing, and its position incumbent on a bed of detrital matter, are circumstances which might entitle it to a place amongst the products of modern volcanos.

But, on the other hand, the section which has been worked through the lava, the pebble bed, and the gneiss underneath, to a depth of not less than 400 feet, is of sufficient importance to rank as a valley rather than as a mere ravine, and thus to place the volcanic matter in the class of ancient igneous products, with which view indeed the basaltic character of the greater part of the lava-current, of which the vertical face is exposed at the point alluded to, seems more strictly in correspondence.

The lava of Chaluzet is not seen on both sides of the valley, and we have therefore perhaps no right to assume that it has been itself cut through by the waters of the Sioule; but at any rate, at the time when it was erupted, the bed of pebbles upon which it rests must have constituted the lowest level of the then existing valley, and the remaining fifty feet, or thereabouts, which have been excavated through the gneiss

* Edin. New Phil. Journ. 1829.

subjacent to this alluvial matter, are attributable to causes in operation since this very remote volcanic eruption.

I will next proceed to instance certain ancient volcanic rocks in the neighbourhood of Clermont of a less equivocal character.

The basalt of Montaudoux, which Dr. Boué has remarked to be nearly identical in character with the rock of Calder, between Glasgow and Edinburgh, evidently belongs to an æra much more remote, and has been formed under conditions altogether different from those of the scoriaceous lava of Graveneire, to which it is so contiguous.

The mountain Gergovia, too, situated a little further to the south, consists principally of a succession of beds of freshwater limestone; but these are intersected by strata of tuff consisting of a mixture of nodules of limestone and of basalt, with kidney-shaped masses of chalcedony imbedded in volcanic clay and sand. A bed of basalt divides the strata of tuff, and the same material caps the freshwater beds, which, resting upon the tuff, form the upper portions of the hill. Elie de Beaumont appears to have proved that these apparently horizontal beds of basalt are in reality dykes intersecting the freshwater formation of the Limagne*; but this fact only places in a stronger light their antiquity, as it is evident that they must have been injected before the excavation of the valley which the mountain of Gergovia overlooks. The fact is also important, as it may assist us in explaining the anomalous position which the basalt sometimes assumes with reference to the trachyte and even to the tuffs subjacent, both which it occasionally underlies, although its general relation to both these rocks indicates that it is of more modern eruption†.

The Puy Charade, on the other side of Clermont, is also capped with basalt much impregnated with olivine, whilst the sides and base of the mountain are composed entirely of granite. These instances are sufficient to establish the greater antiquity of many of the trap rocks near Clermont, and that they are of volcanic origin would have been admitted even by

* Mémoires pour servir, &c. vol. i.

† Burat, in his 'Déscription des terr. volc. de la France Centrale,' cites several instances of this: see particularly chap. viii.

those who contended for the aqueous origin of trap, from their association with beds of tuff containing scoriæ and other cellular products.

Thus at the Puy Marman near Veyre, about three leagues south of Clermont, on the road to Brioude, the same association of rocks occurs as at Gergovia, the mountain being capped by basalt, underneath which is a calcareous rock, identical both in its external characters and imbedded petrifactions with that which occurs in the latter locality. This is followed by a thick stratum, composed, as at the former locality, of a sort of tuff containing imbedded portions, not only of basalt and other trap rocks, but even of limestone. The paste by which these ingredients are held together partakes in some places of the characters of wacke, but where it approaches the bed underneath it, the cement itself becomes calcareous, in which case the only difference between the strata consists in the presence or absence of the imbedded fragments. In like manner the limestone bed is at bottom interspersed with fragments of the volcanic matter, which becoming by degrees more and more frequent, give it at length the characters of a tuff. Basalt also appears to occur interstratified with the rocks above-noticed, although perhaps, as in the former case, intersecting it in dykes; and the whole series, which, from its present highly inclined position, seems to have undergone some change since the period of its original formation, rests finally upon the limestone of the plain of Limagne.

Whether the tuff in this instance contains any scoriform lava, I am not prepared to say; but its origin is clearly the same with that of the other rocks consisting of the same material, which occur in various places resting upon the same limestone in the plain of Limagne.

Two of these rocks occur a mile or two south of Clermont, near the road of Brioude; one of them constituting a little knoll, hardly perceptible until we are close to it; the other attaining a considerable height, and remarkable for the abruptness with which it rises out of the midst of so level a plain, reminding us of the Roche de St. Michael and other eminences which will be noticed as occurring near the Puy en Velay.

The first of these rocks is called the Puy de la Pege or

Puy de la Poix; the other, or larger one, the Puy Crouelle. The Puy de la Pege consists entirely of a kind of tuff, strongly impregnated with bitumen, which covers the external surface with a kind of varnish, and fills all the crevices in the rock. This tuff often contains fragments of vesicular as well as of compact lava, the former connecting its origin with modern volcanic products, the latter with the tuffs of the surrounding country. In some cases the brecciated or conglomerated character of the rock is lost, and the prevailing substance seems to be a species of trap rock, which from the unequal manner in which it has decomposed, exhibits a number of light spots disseminated through a darker ground.

The Puy Crouelle, which is about half a mile distant, is composed of the same tuff equally penetrated with asphaltum. Unaltered portions of the limestone occur in the midst of it, and the same substance constitutes the stratum which immediately supports the tuff. The line of junction between the two formations is, as might be expected, irregular, so that the limestone seems in some places to send up wedge-shaped processes into the incumbent rock. The commencement of the volcanic stratum forms a sort of natural boundary, beyond which no vineyards are to be seen, whether it is that the greater abruptness of this rock prevented their growth, or that the nature of the material itself was hostile to vegetation.

In my Letters to Professor Jameson, I stated it as my opinion that these isolated hillocks of tuff or wacke were raised by some volcanic agency from beneath through the limestone on which they seem to repose, an hypothesis which I see is adopted by a German geologist, M. Steininger, who has written still more lately on the subject*. Nevertheless on reconsidering the question, and comparing the tuff of Limagne with that near the Puy en Velay, I am inclined to believe that these rocks, with others of the same description that lie scattered in the different parts of this district, are relics of a more extensive stratum, the intervening portions of which have been removed.

Difficult as it may seem to suppose so complete a destruction of a rock as is implied in the latter hypothesis, it is still

* M. Burat also (Déscr. des terr. volc. de la France Centrale) favours this view.

more so to reconcile the general phænomena of the tuff—its alternation with Neptunian products, the occasional presence of shells, and of unaltered portions of extraneous rocks, &c.—with the hypothesis of igneous ejection.

Vestiges of a similar tufaceous rock holding the same relation to the limestone are seen in various parts of the plain of Limagne, especially at the town of Pont du Château, where the surface of the stone is coated with those fine chalcedonies so highly prized by collectors; indeed siliceous infiltrations are common everywhere throughout the freshwater formations of Auvergne.

I must not forget a formation somewhat different from the above which occurs a little to the west of the Puy Marman at the hill of Mouton. It bears some resemblance to the trass of the Rhine volcanos, containing imbedded portions of pumice as well as of scoriæ and compact lava; but, like the tuff of the contiguous hill, the paste by which the fragments are held together seems to be often calcareous.

Pumice is not a product of the more modern volcanos of Auvergne, but it occurs extensively west of Issoire on the road to Champeix, especially at Pardines; and it is found also in the tuff of Mont Dor, so that it seems to be characteristic of the more ancient igneous operations of this province.

Now it has been stated in the preceding chapter that pumice is derived from rocks possessing a trachytic character; and we shall find that trachytes do in fact constitute the prevailing formation throughout the older volcanic region of Auvergne. These products however, although, as we have seen, occurring around Clermont, obtain their greatest development in the neighbouring chain of Mont Dor and in the adjoining province of Cantal, where they are seen resting upon tertiary freshwater limestone, and covered by rocks which recall to our recollection the basalts of the plain of Limagne.

Volcanic Rocks of Mont Dor.

The table-land known under the name of Mont Dor embraces a circumference of about thirty leagues, of which the towns of Rochefort, La Tour d'Auvergne and Besse are placed nearly on the boundary line, and the highest point in the

range attains the elevation of 6133 feet (1887 metres) above the level of the sea.

Though its shape at a distance corresponds more to what we observe in many clay-slate districts, yet it appears to be entirely of volcanic origin, and two distinct classes of rocks, both referable to this cause, may be distinguished.

On the surface in many places round the flanks of this mountain-range we observe a basaltic formation, covered by a sort of trap-tuff or breccia, and a highly cellular description of lava. Below this is the porphyritic felspar rock known under the name of trachyte, with which are associated, a conglomerate made up of fragments of the same material, as well as of basalt and cellular lava, cemented by a felspathic paste, and a rock apparently homogeneous, but in reality analogous to trass, consisting of finely comminuted portions of pumice. Underneath them all, but at so low a level as hardly to justify its being considered as making a part of the Mont Dor range, is seen the granite, which seems to constitute the original substratum throughout the whole of this province, passing however into gneiss, and afterwards succeeded, in Cantal, by mica-slate. Its medium height may be 3000 feet or upwards, leaving about the same thickness for the superimposed volcanic matter.

I shall consider these rocks in succession, beginning with the highest in the series:—

1st. The basaltic formation of Mont Dor comprises several rocks, differing from each other much in appearance and external characters.

The material which has induced me to give this name to the whole, is a compact and sonorous basalt, containing occasionally crystals of olivine, and more commonly some of augite and hornblende, the latter having frequently an acicular form.

Associated with it is a vesicular rock, the general aspect of which obliges us to refer it to the same class with the undisputed products of volcanos now in activity. We meet also with scoriæ, either in detached fragments or with portions of compact trap, the whole cemented together by iron-clay, so as to constitute a species of volcanic tuff.

I found the order of superposition on a hill which I examined near Lake Gery, a few miles from the village called "Les Bains de Mont Dor," to be as follows:—

On the summit a thin bed of scoriæ. Underneath, a tuff, containing fragments of the more compact united with the vesicular variety of lava, but in some places in a state of such extreme division, that the whole might be mistaken at a distance for red sandstone. Beneath all was a compact and crystalline basalt, made up of a confused assemblage of these acicular crystals of hornblende, together with augite and felspar.

From the description we have given, it might be collected, that the subjacent rock, the trachyte, is chiefly seen exposed on the sides and in the bottom of the valleys; and that the great and elevated table-land, which composes the range of Mont Dor, and extends with little interruption into Cantal, has its upper strata generally composed of basalt and the other rocks usually found associated with it.

But the basaltic platform alluded to seldom reaches beyond a certain elevation, probably owing to the greater resistance opposed to its emission about the centre of the range where the thickness of the trachyte is greatest, just as the volcanic energy has shown itself on either side of the Apennine range, but not in the centre of the chain. In many places indeed, especially on the flanks of Mont Dor, it is found at a lower level than the greater part of the porphyritic stratum.

Thus at the "Cascade du Quereuil," near the Baths, the basalt is seen in fine columns incumbent upon a rock, which, from its analogies to one found among the Rhine volcanos, I shall call trass, and covered with volcanic tuff. Now as the former rests immediately upon granite, without the intervention of any trachyte, a recent German writer, M. Steininger, has concluded that the latter formation probably lies above this basaltic rock, and consequently that the Mont Dor range contains two sets of basaltic lavas, the one superior to the trachyte, the other occurring in the midst of it. But as this geologist does not appear to have adduced any decided instance in which the trachyte is seen superimposed on the basalt, it may be better to imitate the caution of M. Ramond, whose experience in the geology of Auvergne is probably greater

than that of any other observer, and who, without altogether denying the fact of an alternation between the two formations, confesses that the general aspect of the phænomena leads him to conjecture, that the irregular disposition of the basalt may be explained by supposing it to have descended from the highest points of the chain, and to have filled up the hollows and crevices in the porphyritic mountains beneath.

At all events, the parallel which Steininger has attempted to draw between his two formations of basalt in the Mont Dor, and the ancient and modern basaltic lavas near Clermont, fails in a very essential point, since the most modern of the volcanic rocks of Mont Dor have been produced antecedently to the formation of the valleys, whilst those near Clermont are, as we have seen, in general posterior to them.

There is indeed near a little lake, called the Lake of Servières, which stands on the summit of the table-land, and in its form resembles a crater, a rock in height not exceeding fifty feet, which, from its conical form and the analogy which the substances composing it bear to the products of recent volcanos, seems to be more modern than those in its vicinity *.

This fact however does not affect the question with regard to the general antiquity of these basalts, which, supposing them to have been thrown out since the existence of the present valleys, would have been found at the lowest levels of the country.

2. The trachytic formation is essentially composed of crystals of glassy felspar, imbedded in a base which seems to be

* Others are also mentioned in Scrope's Memoir, p. 116, and one of them is deserving of notice, as an instance of a class of volcanos, which, as we shall find, are of more frequent occurrence in the Eifel. It is a circular lake, called " Le Gour de Tazana," about half a mile in diameter, and from thirty to forty feet deep. Its margin for a fourth of the circumference is flat, and elevated above the valley into which the lake discharges itself. Everywhere else it is environed by steep granitic rocks, thickly sprinkled with small scoriæ and puzzolana, and rising about 200 feet from the level of the water. These fragments are all that indicate the volcanic origin of this gulf-like basin, but they are sufficiently decisive. No stream of lava, or even fragments of any large size, are perceivable. (See p. 79 of Scrope's Memoir.)

of the same material. Its fracture is more commonly rough and earthy, but is not unfrequently compact. In the latter state mica, hornblende and other minerals are found imbedded, whilst it is the former variety which contains the finest and most regular crystals of glassy felspar. It passes sometimes into pitchstone porphyry, as at the Vallée d'Enfer, at other times into a kind of hornstone porphyry, both found near the village where the Baths are situated.

It is frequently coloured red by iron, and now and then incloses flattened balls of clay ironstone. In its fissures are also found plates of specular iron ore, a substance which I have noticed as occurring among the recent volcanos near Clermont, and at the Puy de Dôme.

Associated with the trachyte, and in some places interstratified with it, are those singular beds which I have compared with the trass of the Rhenish volcanos, consisting of an apparently homogeneous rock bearing a resemblance to tripoli, possessing a rough earthy feel and slaty fracture, generally grey, but sometimes of an ochreous yellow colour, from the intermixture of oxide of iron.

Whether these beds are to be attributed to the disintegration of the trachyte, and the subsequent agglutination of its finely divided fragments into an uniform mass, or whether they have not rather been the result of ejections of finely pulverized matter, may admit of dispute. The same uncertainty extends to the beds of volcanic breccia likewise found accompanying this formation, in which the inclosed portions are cemented by a paste often resembling the trachyte itself.

To the latter we may probably also refer those fragments of a breccia containing sulphur and alum rock*, found in the Gorge d'Enfer, near the village of the Baths, in the bed of the river Dordogne, which takes its rise in the mountains above.

Of this rock M. Cordier has published in the 'Annales des Mines' a description as well as an analysis, and from both these he infers that it is analogous to the alum rock of Tolfa,

* Nöggerath, in the German translation he has published of these Letters, justly remarks, that alum rock and alum stone must be distinguished, the former serving to designate a species of rock, the latter a simple mineral. See also Leonhard's 'Characteristik der Felsarten,' vol. ii. p. 553.

like which it yields, on exposure to heat and moisture, numerous capillary crystals of alum. It has never been met with *in situ*, but it seems probable that if the middle regions of the Pic de Sancy, above the spot to which it has been brought by the torrents, could be explored, the beds of tuff which there exist might be found to contain it.

The following is the result of Cordier's analysis of the alum rock of Mont Dor, compared with that of the alum rock and the alum stone of Tolfa, Hungary and Montione:—

	Alum rock of Mont Dor.	Alum rock of Tolfa.	Alum rock of Tolfa.	Alum stone of Hungary.	Alum stone of Tolfa.	Alum stone of Montione.
	Cordier.	*Vauquelin.*	*Klaproth.*	*Klaproth.*	*Cordier.*	*Collet Descotils.*
Sulphuric acid...	27·03	35·00	16·5	12·50	35·495	35·6
Alumina	31·80	43·92	19·0	17·50	39·654	40·0
Alkali	5·79	6·08	4·0	1·00	10·021	13·8
Water	3·72	4·00	3·0	5·00	14·830	10·6
Silex...............	28·40	24·00	56·5	62·25		
Oxide of iron ...	1·44	......	......	......	a trace	
Loss...............	1·82	......	1·0	1·75		
	100·	100·	100·	100·	100·	100·

In my Letters to Professor Jameson, published in the fourth number of his Journal, I noticed some dykes of vesicular lava which traverse the tufa at the waterfall called the Grande Cascade de Mont Dor*.

From the absence of any dislocation or hardening of the rock which they traverse, I inferred that they were processes given off from the basaltic lava of the cliff above, which might have insinuated itself in a liquid state into the cracks or fissures of the subjacent rock, rather than the rents caused by the basalt in the act of attaining the position which it now occupies.

I perceive that M. Ramond adopts the same opinion with reference to the place in question †, which indeed is confirmed by the fact of the dykes appearing to terminate in the tufa beneath; but I must at the same time remark, that in the volcanic districts which I have since examined, the dykes that

* In this section we observe the superposition both of trachyte and trachytic conglomerate on basalt: see Scrope's Memoir.

† Nivellement Barométrique de Mont Dor.

appeared to be of the most modern date did not seem to have so generally affected the rock contiguous, as the more ancient ones had done.

I should also expect, from what I have since seen among the German volcanos, that the basalt which caps the table-land of Mont Dor has been ejected through the medium of *dykes* rather than of *craters**, and it is therefore not improbable that those of the Grande Cascade de Mont Dor may be among the number of these vents. I am still however of opinion, that the dykes of volcanic tuff that occur in Cantal, of which several are mentioned by Steininger, and one has been noticed by myself in the communication alluded to, are nothing more than an upfilling of fissures that existed in the subjacent rock; and I am confirmed in this idea from having seen at the foot of the Siebengebirge, on the Rhine, similar veins of trass filling up the cracks in a rock of the same description which there encircles the trachyte.

Although trachyte rests immediately upon granite, and therefore constitutes the oldest volcanic formation of the district, it is nevertheless seen rising also to the most elevated portion of the range. Thus the Pic de Sancy, the highest point above the valley of the Baths, and the other eminences which form together the crest of the hills which we cross on our road from thence into the Cantal, are composed of trachyte which is also seen traversing in dykes the subjacent tuff.

Other eminences which rise above the table-land of Mont Dor, as the Peaks of Sanadoire and Tuillière, consist of porphyry slate, or clinkstone, which some regard as a modification of trachyte; but as this rock occurs more extensively in Cantal, I shall reserve the consideration of it till I come to speak of that province.

From the above brief description of the geological structure of the Mont Dor range, it will be readily collected, that although volcanic, it presents few features of resemblance to the vicinity of Clermont. Indeed not only are the individual rocks more compact, and the amount of scoriform matter,

* Steininger, in his Tract on Auvergne above cited, notices dykes of trachyte near Murat, and of basalt at Theyzac, both in Cantal. I did not observe them.

except it be pumice, less considerable, but their general configuration collectively taken bears more analogy to that of the metamorphic or stratified rocks which occur in other localities than to the ordinary constituents of modern volcanos.

MM. Dufrénoy and Elie de Beaumont, in their Memoir*, conceive, that its structure may be best explained upon the supposition that the volcanic rocks composing the entire district were at first spread almost horizontally over the surface of the subjacent granite; that afterwards they were heaved up in three different points, the Puy de Sancy being the centre of one elevation, the rocks Sanadoire, Tuillière, &c. of the second, the Puy de la Tache of the third. These are all points of the greatest elevation that occur in the vicinity of the Baths of Mont Dor, the latter standing in a valley which was caused originally, not by the erosive action of water, but by the disruption in the rocks themselves consequent upon the elevation of the range at these several points.

It is evident that the strata would be inclined in every direction from the points at which the elevatory movement took place, and it is also evident that great clefts or fissures would be formed on the slope of the cone, as the surface over which the elevated mass would be spread must be more extended than that which it occupied when in a more horizontal position.

Elie de Beaumont has given a mathematical aspect to the discussion, by calculating what proportion the fissures ought to bear to the size and altitude of the elevated mass, and has laboured to show, that the actual condition of those both in Cantal and in Mont Dor corresponds with this calculation.

Such questions however will come before us at a later period, and all I need at present say with respect to the structure of Mont Dor is, that the difficulty of referring those sheets of trachyte and of conglomerates which constitute the principal mass of the Mont Dor range, to any series of operations of the kind we witness in an existing volcano, as well as that of explaining by the action of running water the formation of deep valleys like that in which the Baths are situated, may reconcile us to having recourse to an hypothesis which assumes a more powerful and violent operation of these same igneous agents, than is experienced under present circumstances.

The French geologists alluded to lay great stress also on the decided difference of structure existing between the volcanic rocks of Mont Dor, and those which have been erupted in more modern

* Mémoires pour servir, ete., vol. ii.

times near Clermont,—a distinction which I had made the basis of my classification of the rocks of Auvergne into *ante-diluvial* and *post-diluvial*, or, as at present, into *ancient* and *modern*.

They contend that there is no instance of a modern *coulée*, which has flowed down a slope so much inclined as that of the mountains under consideration, assuming a basaltic character, a surface nearly level being essential for that tranquillity in which the lava must remain during the period of its cooling, in order that the particles should arrange themselves in a compact and crystalline form.

Volcanic Rocks of Cantal.

In describing the rocks found at Mont Dor, I have said almost all that appears necessary respecting the trachyte of Auvergne, for that in the Cantal is distinguished chiefly by its more compact form, and by the rarer occurrence of scorified matter intermixed.

This formation is also occasionally capped with basalt, as at the Plomb du Cantal, the highest point in the range, and the same rock likewise descends, as it does at Mont Dor, to a comparatively low level; so that Steininger has adopted with respect to it, the same hypothesis with regard to the existence of a basaltic formation interstratified with trachyte, though apparently without adducing any more decided proofs of such an alternation *.

The highest rocks in Cantal are, however, mostly capped with the same porphyry slate which is found at Mont Dor, composing the two isolated peaks near Rochfort, called Sanadoire and Tuillière.

The mineralogical characters of this rock approach so nearly to those of some varieties of trachyte, that Daubuisson regards it as a modification of that rock †; but in the case before us, there does not appear to be any passage from the one into the other, and the limits of the two formations are very distinctly marked, especially in the former instance, by the more harsh and rugged outline of that portion of the

* See Steininger, Erloschenen Vulkane in Süd frankreich, p. 202.

† This opinion is also adopted by M. Burat (Désc. de France Centrale, p. 76); but he admits that the trachytes composing the upper parts of the hills have much of the characters of clinkstone, although the latter is actually confined only to one locality, between the valleys of the Cère and the Jordanne.

mountain which is composed of porphyry slate. From the indestructible nature of this rock, the hills in Cantal are usually covered towards their surface with massive fragments of a greyish colour and great hardness, whereas the trachyte beneath decomposes in a more rapid and uniform manner.

Nor can there be a greater contrast than between the luxuriance of some of the valleys, as that of Theyzac, in which the substratum is of trachyte, and the extreme barrenness of the higher parts, which are composed of clinkstone.

I am therefore inclined to believe this rock to be a formation distinct from the trachyte underneath it, of the same age probably as the basalt of Mont Dor; and when we recollect, that in the Siebengebirge, near the Rhine, basalt and trachyte occur together without any determinate order, and that in the hills near the Lake of Constance, the former species of rock is found associated with clinkstone in such a manner as leads one to suppose that both are products of the same æra, we need not be surprised at seeing the porphyry slate in Cantal take the place of the basalt, which is spread over the surface of Mont Dor.

I have already alluded to the tuff which, in the latter chain, is found associated with trachyte. A similar rock occurs in greater abundance throughout Cantal, and is there distinguished by the grotesque appearance which it assumes, presenting to the eye a range of mural precipices, broken into a number of fantastic shapes,—a circumstance very characteristic of rocks of this description, both here and in the neighbourhood of the Puy en Velay.

In Cantal the tuff is best displayed near the village of Theyzac, on the road from Aurillac to Murat, where it is placed between two beds of trachyte, being found rather less than half-way up on either side of the hills which bound the valley, whilst the summit and base alike consist of trachyte. It dips gradually to the east; so that about half a league from Theyzac, on the road to Murat, it reaches the level of the road. Different as the tuff appears from the trachyte which it accompanies, it will be found on examination, that the fragments which it contains are cemented always by a

basis of the latter rock, and that a passage from the one to the other proceeds by imperceptible gradations. The fragments consist, in general, of a trachyte of a more compact character than the paste which cements them, but we also find basalt and cellular lava intermixed; and I remarked beds or veins of the same description of stone, which, when speaking of Mont Dor, I have compared to the trass of the Rhine volcanos. A little beyond Theyzac, near Vic en Carladez, a mass of this rock occurs included apparently in the midst of the tuff, and with its layers irregularly incurvated, forming a sort of arch, which, though on a smaller scale, reminded me of one of clay porphyry which I had observed in Arran, and which is represented in the plates to Dr. Macculloch's work on the Western Islands.

The tuff in some places, as at Salers, is composed of minute fragments so highly charged with oxide of iron, that it has much the appearance of a ferruginous sandstone. In this state it sometimes contains impressions of leaves and branches of trees, which appear in no respect mineralized, but are carbonized and reduced to an impalpable powder by the ordinary process of decay. In other cases, where the tree has wholly disappeared, the hollow which it occupied in the midst of the tuff still remains. This circumstance tends, in a still greater degree, to identify the tuff of Auvergne with the trass of the Rhine volcanos.

The greater part of this rock, no less than the trachyte of Cantal, appears to be posterior to the calcareous formation of the valleys; in one instance only, in the valley of Fontanges, have I observed any appearance of alternation between them, in which case a thin calcareous bed of considerable hardness is seen resting upon a tuff in which the fragments are held together by a trachytic base, and which is covered by the same material.

This appearance however is probably deceptive, and may have arisen from the dislocation occasioned in the freshwater strata by the eruption of the trachyte.

Many instances of this disturbance occur between Aurillac and Murat, and numerous fragments of calcareous rocks, and of their accompanying flints, are scattered over the trachytic conglomerates.

There is therefore nothing to prevent our referring the oldest volcanic rocks of Cantal to a period somewhat more recent than that of the freshwater rocks of the district, which latter appear to be of the same age as those of the plain of Limagne.

Now Mr. Lyell has shown that the freshwater formations of Central France are referable to the Eocene period, or to the oldest of his tertiary series, from their containing only a small number of living species of testacea.

The discovery of bones belonging to the Mastodon, and to extinct species of several existing genera of animals, in a bed of fine sand covered by the volcanic tuff of Mont Perrier near Issoire *, completes the analogy between the tertiary beds of Central France and those of the Paris basin †.

The resemblance which they bear in the Cantal to chalk,—a resemblance rendered more striking from the abundance of flints which are interstratified with the rock,—struck me forcibly in my tour through that province, and as Mr. Lyell observes, is well-calculated to put the student upon his guard

* This discovery is announced in the Bulletin des Sciences for November 1824, p. 328, in an extract from a memoir read by M. le Comte Laizer at the annual meeting of the Philosophical Society of Clermont in Auvergne. Between Champeix and Issoire, an elevated platform occurs, 2000 feet above the sea, which consists of a bed of alluvial matter, composed of fragments of pumice and trachyte cemented by the usual argillaceous paste. It is overlaid by and alternates with masses of trachytic breccia. The hill is capped with basalt. In the alluvial bed are the bones of no less than twenty extinct species of Mammalia, several of which have been pronounced by Cuvier to be new.

Among the Pachydermata are, the Mastodon, Elephant, Rhinoceros, Hippopotamus, Tapir.

Ruminantia—two species of Ox like the Auroch, and two species of Stag, —all four extinct.

Rodentia—a Beaver.

Carnivora—two new species of Bear, three species of the *G. Felis* like the Panther, one species of Hyæna, one species of Fox, one species of Otter, —all of them new.

Besides the above, occur bones of Birds and impressions of Fish.

† The repeated alternations of trachytic breccia and alluvium containing fossil bones at this locality are strongly insisted upon by Messrs. Lyell and Murchison, in proof of the long intervals of time which must have elapsed between the several volcanic eruptions, as well as of the impossibility of referring these alluvia to other than existing causes.

against too implicit a reliance on lithological characters as tests of the relative ages of rocks *.

With regard to the general structure of the mountain group just described, M. Elie de Beaumont observes, that it is still more simple than that of Mont Dor, constituting in the aggregate one single elliptical cone channeled in its centre, and intersected by valleys with abrupt sides radiating towards the circumference.

For reasons similar to those I have briefly stated with reference to the similar group of Mont Dor, he conceives that the rocks composing it occupied a nearly horizontal position when first poured forth from the interior of the globe; but that they were afterwards made to assume their present conical form by an elevatory movement, the focus of which he places underneath the Puy de Griou.

This, with the Rock of Usclade and two other eminences, all composed of porphyry slate, are the four culminating points of a ridge embracing three-fourths of a circle, with a hollow in its interior now forming an excellent pasturage.

From this central point, the valleys of Mandailles, of Vic, of Murat and others diverge, and from it the beds of trachyte, of basalt, and of conglomerate dip in all directions, at an angle not exceeding 12°.

This then, according to the above eminent geologist, was the point at which the elevatory movement took place, and the above-mentioned valleys are the fissures originally caused by the force which compelled that inelastic mass to assume an inclined position instead of its original one, which was horizontal. The two principal valleys, that of Mandailles and of Vic, present a series of escarpments receding one behind the other, which contrast in a very marked manner with the gentle inclination of other minor valleys produced by aqueous erosion.

M. Elie de Beaumont has entered into the same calculations here as in the case of Mont Dor, and maintains that the width and number of the fissures caused by the disruption correspond in fact with those which ought to have resulted from the elevation of such a mass of rock to the height which it now possesses.

Volcanic Rocks in the Velay.

About fifty miles further to the south, in the neighbourhood of the town of Puy en Velay, an extensive formation of

* Lyell, Princ. Geol. vol. iii. p. 238.

tuff occurs, resting on strata of tertiary formation, but covered by alluvial detritus.

The tuff is composed of fragments of scoriform lava and basalt, with the debris of various other rocks, all cemented together by sand and wacke. It appears at one time to have overspread the valley in which the town of Puy is situated, but since to have been in great measure swept away by the action of water and by other causes. Owing however to the unequal degree of consistence possessed by different portions of this formation, it has been affected by these agents in a very irregular manner; and hence it has happened, that in the midst of the valley caused by the destruction of the tuff, several detached hillocks appear, which, from their singularly abrupt and almost pyramidal form, look at a distance rather like artificial constructions than the result of natural causes.

Such is the hill on which the cathedral and part of the town of Puy is situated—that near the village of Expailly, celebrated for the crystals of zircon and hyacinth which it contains—and still more remarkably the rock of St. Michael, the height of which, according to Faujas, is 200, whilst its diameter is only 170 feet *.

It is curious that the same tapering figure which we view with surprise in the Alps, and consider as characteristic of rocks of the most compact texture, should in this instance be found belonging to a stratum consisting of loose materials and of a date so modern †.

* "Une espèce de grande obélisque, façonné des mains de la nature." Faujas, Volc. du Viv. p. 342.

† Sir John Herschel has however given the Geological Society an account of a still more abrupt figure belonging to hills made up of even more unstable materials. It occurs in the Tyrol, where masses of diluvial matter, consisting of pebbles loosely cemented by sand, are seen to form a succession of pyramidal hills even more precipitous than those of the Puy. In this instance the effect is explained by observing that the portions of the diluvial matter which rise in this abrupt manner above the rest have been protected from the action of rain, for we may observe on the top of every one of these a large stone which shielded the parts immediately underneath it.

I have observed a somewhat similar effect in the Spanish province of Estremadura, resulting from the indestructible character of the quartz

The tuff about the Puy is also associated with masses of compact basalt, which seem in general to rest upon, but in some instances have the appearance of being intermixed with it. Thus, near the tufaceous rock of Expailly, just noticed, is another isolated knoll, which consists of columnar basalt, and in like manner, at St. Pierre Eynac, a village at a short distance from the Puy, the basalt seems to alternate in beds with the tuff.

It appears to me, that a key to the true explanation of these phænomena may be obtained by considering the structure and position of an isolated mass of basalt near the Puy, called the *Rocher Rouge*. This rock is superimposed on the slope of a granitic hill, from which it rises to the height of more than 100 feet, and has all the appearance of an enormous dyke, both from the shattered condition of the granite round it, and from the manner in which the latter is seen on one side to lean against the protruding mass.

Where the granite has been by accident removed, the basalt is seen rising as it were from beneath it; and from the principal mass are seen to spring two dykes, which penetrate the former rock horizontally to a considerable distance. Fragments of granite are also to be met with imbedded in the substance of the basalt.

Yet notwithstanding these unequivocal proofs of igneous ejection, it seems impossible that the basalt should have originally stood in the position it now occupies, unless it had been at that time supported by some surrounding stratum; and the most simple explanation consequently is to suppose that the granite in this situation was once covered with tuff, which the action of the waters has since swept away.

By the occurrence of similar dykes thrust up in other places through the midst of the tuff, and sometimes penetrating it horizontally, I should account for the basalt seen intermixed with, as well as covering this volcanic breccia.

rock which caps the clay-slate formation of that district. Hence those low ridges of hills with flattened summits, which here and there intersect the comparatively level surface of the clay-slate formation, have arisen from the quartzose covering which protected these portions from the action of the elements. See Memoir on the Phosphorite of Estremadura, Royal Agric. Journal, vol. v. part 2.

I cannot pretend however to have studied the geology of this neighbourhood with the attention requisite for determining the relation of all the rocks included under this series to each other, and must therefore refer to M. Bertrand Roux's* excellent description of the environs of Puy for further particulars.

From his statement it would appear that the volcanic rocks of this neighbourhood are of very different ages, although he infers the extreme antiquity even of the most modern of them by contrasting the depth to which they have been excavated, and the vast quantity of matter removed, with the almost imperceptible amount of decay which has taken place in the same rocks since the Christian æra, as shown in the old Roman roads, none of which can be less than 1300 years old, by the side of which the rock has since undergone scarcely any sensible abrasion.

A limit on the other hand is set to the age that can be assigned to this volcanic breccia, by the circumstance of its being superposed on strata containing freshwater shells and bones of mammalia † similar to those of the basin of Paris. Hence the eruptions to which the materials of this tuff owe their existence must date their commencement from a period somewhat subsequent to that of the Eocene formation.

The same remark will apply to that extensive volcanic formation near the Puy which ranges from south-east to south-west, forming the elevated ridge which separates the Velay from the neighbouring province of the Vivarais.

The principal rocks in this district are trachyte and porphyry slate, the latter generally superimposed; on the flanks however are occasionally seen detached patches of basalt, which seem to belong to the formation covering the tuff on the hills about the Puy.

It would nevertheless appear, that the whole of this

* Déscript. des envir. du Puy en Velay, 1823.

† Cuvier has ascertained that they belong to the genus Palæotherium and Anthracotherium; the former contained in a gypseous deposit similar to that of Montmartre; the latter in a calcareous rock, in which were found freshwater shells. The same bed inclosed bones of other mammalia, and portions of the shell of the Turtle.

trachytic mass was of later date than the tuff, no beds of conglomerate being found alternating with it, and no fragments of trachyte or clinkstone existing in the tuff which occurs in the valleys below, except indeed in the very uppermost members of that formation, which are met with chiefly on its western slope.

It would therefore seem, first, that the emission of trachyte was not accompanied with ejections of pulverulent or fragmentary materials; and secondly, that its production must be assigned to the epoch at which these upper beds of tuff were deposited, and consequently to a comparatively recent period in the history of our planet.

Are we then, it may be asked, to ascribe the abrupt, and sometimes almost pyramidal form of many of these phonolitic eminences to the slow erosive action of atmospheric agents? The small amount of detrital matter seen at their base, as well as the insignificance of the streams which either now or at any former period can be supposed to have been instrumental in moulding their external surfaces, seem opposed to such a supposition, whilst the sharpness and tapering character of their summits show that they cannot have stood originally quite so isolated and detached as they do at the present time.

Upon the whole, it seems most reasonable to suppose, that their original form from the commencement approximated to their actual one, and that they were produced in consequence of a greater accumulation of volcanic matter taking place immediately around the points of emission than would elsewhere occur.

The most elevated point in the trachytic and clinkstone formation of this part of France is the Mont Mezen *, which rises to the height of 5900 feet above the level of the sea; and the next in point of height is the singular conical hill called Gerbier de Jones, which is composed entirely of clinkstone porphyry, so fissile as to be used for a roofing slate.

Near the Mont Mezen I observed a small lake, that of St. Front, having somewhat the appearance of an extinct crater;

* Or Mezene, as Burat spells it.

but there is little in the character of the surrounding rocks to countenance such an opinion *.

The whole indeed of this elevated table-land appears to have been formed, not only at a very ancient period, but, like the Cantal and Mont Dor range, under different circumstances from those of existing volcanos, no craters being found anywhere in this district; although, as the tuff which mantles round its eastern slope contains no fragments of trachyte or of phonolite imbedded, it may be inferred, that the rock which constitutes the summit of the Mezen and other high points has been thrown up through the midst of the tuff by the agency of subterranean heat.

Thus, during a period antecedent to that at which man and other existing species of mammalia first came into being,—at a time when the lower parts of the country were still under water, but the higher had become peopled with various tribes of land animals, the neighbourhood of the Puy appears to have been agitated by volcanos, which, overspreading the country with their ejected materials, may have caused the destruction of the animals that existed there; and, according to M. Roux, by obstructing the drainage of the district, have raised the waters to a still higher level than before. The ejected materials, intermixed with fragments of older rocks washed down at the same time from the neighbouring high ground, would be deposited at the bottom of the water, forming those immense masses of tuff which now cover the valley of Puy; and during the latter part of the period occupied by this process, the same volcanic forces which had before poured forth these melted materials, may be supposed to have elevated from the midst of the then existing lake, the trachytic rocks which constitute the ridge of Mont Mezen.

But besides these traces of volcanic action at a period antecedent to the formation of the valleys, the neighbourhood of the Puy, no less than the province of the Vivarais which bounds it on the south-east, exhibits also decided evidence of eruptions of a more modern date.

* M. Burat, however (p. 236), has endeavoured to explain how such a crater might have been produced.

West of the town of Puy is a series of little volcanos, amounting, according to M. Bertrand Roux, to more than a hundred, the two most remarkable of which are, the Lac de Bouchet and the Crater of Bar. The former, which is situated near the villages of Cayre and Bouchet, is of an elliptical form, and without any outlet. Its depth is about 90 feet, and its greatest diameter 2300. The character of the rocks in its neighbourhood corresponds very well with the idea of its volcanic origin. The Crater of Bar is placed on an isolated mountain in the midst of granite, forming a truncated cone about 20,000 feet in circumference at its base, and 830 in height. It is composed entirely of *lapilli* and scoriform lava, and on its summit is the crater, 1660 feet in diameter, and 130 in depth, which is almost perfect. It appears that a lake once existed there, but it is now nearly dried up *.

Modern Volcanos of the Vivarais.

But the most remarkable instances of modern volcanic action, if we permit ourselves to apply the term *modern* to all those igneous products that have followed the course of the now existing valleys, are to be seen in the Bas Vivarais.

They have been described in detail by Faujas St. Fond, by Mr. Scrope†, and others; on the present occasion I shall only pretend to notice two or three, which will impart some idea of their general characters and their relations to the subjacent rocks.

One of the most remarkable of these is the one called the Coupe au Col d'Aizac, near the town of Entraigues. It is a conical hill, which has given rise to a stream of basaltic lava, traceable on the one hand from a crater-shaped cavity on its summit, and to be followed on the other to the very bottom of the valley at its foot.

Here also the Volant, a stream, the course of which was at one time obstructed by the lava which flowed into the valley, has cut itself a new channel through the midst of it

* See M. Bertrand Roux sur les env. de Puy.

† Mr. Scrope enumerates six perfect volcanic cones, viz. Ayzac, Montpezat, Burzet, Thueyts, Jaujac, and Souillols. I have only particularized the first two.

to the depth of no less than seventy feet; and the portion of the rock which forms the bed of the river, or lies immediately above it, alone exhibits a columnar arrangement.

The same remark applies to that line of basaltic columns, connected probably with the same current, which is seen extending along the borders of the river Volant, between Vals and Entraigues, for these also, though they doubtless extend above the level attained by the stream at present, are nevertheless confined to the lower portions of the rock.

Similar basaltic colonnades occur in many of the other valleys that intersect the mountains of the Vivarais, and I believe their position in every instance corresponds with that already pointed out.

Another conical hill from which a similar current of lava has proceeded is La Gravenne de Montpezat, so called from the fine arenaceous scoriæ with which its surface is covered.

The lava stream is of a basaltic character, and may be traced continuously into the valley in which the village of Montpezat is situated. Here, having intercepted the course of the river, it has been cut through in more than one spot by the gradual operation of the waters, and beautiful ranges of columns are in consequence displayed along the course of the present rivulet.

Along the borders of the river Aulière, near the village of Columbier, the following section is exposed:—

1st. At the base of the hill on the borders of the river is a bed of rolled pebbles, consisting of the granite and older volcanic rocks of the neighbouring province.

2nd. Resting on this is a bed of quartzose sand mixed with particles of black lava.

3rd. Next occurs black porous lava covered by the prismatic basalt, which latter serves as a support for masses of the same porous lava as before, extending upwards for 200 feet towards the conical portion of the hill of Montpezat, from which it has descended*.

I shall not detain my readers by enumerating the other volcanic products of the same age which I noticed in the Vivarais, as my examination was of a very hasty nature, and limited to ascertaining their general relations. There is in-

* See Faujas St. Fond, Volcans du Vivarais.

deed so much of a common character in the modern lavas of that country, that a detailed description would be of more interest with reference to the topography of that part of France, than to the natural history of volcanos in general, and is now at least superseded by the publication of the beautifully illustrated Memoir of Mr. Scrope. Compared however with the products of Etna and Vesuvius, they present one important difference, namely, in their more compact and basaltic appearance; connected with which is the general occurrence of a columnar arrangement, not like that rude approach to the same, which, in the latter localities, is attributable merely to the contraction, and consequent splitting of the mass, but one arising probably out of a tendency in it to form a series of globular concretions, which latter the pressure exerted by the parts upon each other has reduced to prisms more or less regular, according to the circumstances of the case *.

The great similarity that exists between the volcanic formations of Auvergne and of the Vivarais, in age as well as in character, is sufficiently apparent from the facts already stated.

In both cases we have proofs of volcanic eruptions, which seem to have taken place since the principal valleys were excavated, and when the country, in all its leading features, had assumed its present physiognomy, although it may be doubted whether even the latest of them have not preceded the earliest dawn of history or tradition.

With respect, indeed, to the volcanos of Auvergne, I have

* Mr. Scrope remarks, that there is evidence of a most powerful contraction having taken place in the columns, from the circumstance that the imbedded knots of olivine which frequently occur in them are severed apart by the seam which separates two contiguous columns. Hence he argues, "that it is impossible to talk any longer of the columnar structure being occasioned by the mutual pressure of spherical concretions." To this I may reply, that a degree of contraction sufficient to produce a seam might very well take place in the columns *after* they became consolidated, as happens in glass and other bodies; and that the mutual pressure by which the spherical concretions are supposed to have been converted into irregular prisms would occur previously to their consolidation, whilst in a soft and pasty state. But this question will be considered more fully in a subsequent part of my work.

already endeavoured to maintain, in opposition to the authority of a learned critic, that their eruptions had terminated before the period of the Roman invasion; and although the testimony of Sidonius Apollinaris and of Alcimus Avitus should persuade us that some indications of activity were manifested, about the fourth century after Christ, by the igneous agents that may be supposed to exist in the bowels of the earth at no great distance from the city of Vienne *, yet it would seem more probable that the reports of these writers had reference to earthquakes, than to true volcanic eruptions that occurred in this district.

One thing at least appears certain, namely, that the phænomena recorded must have been confined within a very short period of time; for no writer anterior to that epoch appears to have noticed anything of the kind, nor has any revival of igneous operations taken place in the province subsequently.

Now although we have many examples of volcanos which have never given out more than a single stream of lava, yet I know of none, where an entire volcanic district, after having shown symptoms of renewed activity at any one period, has sunk immediately afterwards into unbroken repose. Such at least has not been the case at Vesuvius, after it awoke from its slumbers in the first century of our æra, nor at Etna, after it had burst forth afresh in the time of Pindar and Thucydides; whereas Asia Minor and many other localities afford examples of extinct volcanos, like those of Central France, which have, within the historical period, become the theatres of fearful earthquakes, although occurring only at distant and uncertain epochs.

I am inclined therefore to ascribe to the most modern class of volcanos in Auvergne and the Vivarais, the same remote antiquity †; and in like manner it would seem, that

* There are no volcanos near Vienne, but the bishop's diocese may have extended into the neighbouring department of Ardeche, where they occur so abundantly.

† M. Burat is disposed to regard the most modern eruptions of the Vivarais as more ancient than the latest of those of Auvergne, for he remarks, that in the case of the latter, at Aidat and elsewhere, the river has not had time to cut through the opposing barrier of lava, whereas in the Vivarais,

those of a more ancient date in both districts belong to a similar age, as the trachytes and tuffs in either are superimposed on calcareous and other rocks appertaining to the Eocene period.

In either case, the general tenor of the phænomena might lead us to the conclusion, that at the time when these latter-mentioned eruptions occurred, the waters of the ocean had retired from the country; but that there existed in the low land extensive lakes, to which we may attribute the formation of the calcareous and gypseous deposits with freshwater shells, seen alike in the valleys of Cantal, of the Limagne, and of the Puy.

These eruptions seem to have given rise more generally to a volcanic tuff or breccia, but associated with the latter are those trachytic lavas, which we refer to the same, or to a somewhat more recent epoch. The trachyte of Cantal, for example, seems to be contemporaneous with the tuff which rests upon the Eocene limestone at Salers; but its greater compactness, and the absence of cellular products, lead us to imagine it more ancient than the analogous formation which I have described as existing at the Mont Dor. This corresponds well with what M. Bertrand Roux has inferred with respect to the age of the trachyte and porphyry slate of the Mezen, which, from the occurrence of fragments of these rocks only in the upper strata of the tuff, he concludes to be more modern than the greater part of the latter deposit.

Volcanic Rocks of the Cevennes.

Evidences of volcanic agency are not exclusively confined to the districts of France we have been considering; they occur likewise still farther south, among the Cevennes, and near the shores of the Mediterranean in the neighbourhood of Marseilles and of Montpellier.

Of these the rock which has been most noticed by geologists is that of Beaulieu, near Aix in Provence, described by Saussure, Faujas St. Fond, and still more lately by Menard de

where lakes formerly appear to have been produced by similar obstructions, they now cease to exist, owing to the removal of the basalt which once obstructed the stream and the entire restoration of its bed.

Groye*. It is stated by the latter as being about 1200 fathoms in length, and 600 or 700 in breadth, whilst it rises to about 200 fathoms above the level of the sea. It is composed of basalt, which, as we trace it downwards, is seen to pass into a very crystalline greenstone, and is covered by an amygdaloidal wacke, the cells of which, probably from the decay of the rock, are empty near the surface, but in the interior are filled with calcareous matter. The latter is sometimes so diffused through the substance of the rock, that it forms with it a kind of breccia, and even swells out into nests or geodes of considerable size, imbedded in the midst of the tuff. Shells are also contained in this formation, and serve to connect it still more closely with the limestone covering it, the recent origin of which may be inferred from the existence in it of bones of ruminating animals. This limestone is compact, and passes into a siliceous kind of rock, probably a chert, called by Haüy *quartz agate calcifère,* which M. Marcel de Serres considers to be posterior to the second freshwater formation of Cuvier and Brongniart, an inference he is disposed to extend to the volcanic products of the department of Herault †.

The latter constitute a chain for the most part continuous, which pursues a very determinate direction from north to south.

The volcanic formation indeed commences at the most northern extremity of the department, where it is seen in its greatest force, attaining at Escandolgue an elevation of 667 metres (above 2000 feet); it is prolonged almost without interruption as far as the centre of this province, assuming its largest development about Neffier, Caux, Pezenas, and St. Thibery; and it extends from thence to the south, passing by Agde, and losing itself in the bed of the Mediterranean at the fort of Breseau.

This band or chain of volcanos then traverses the whole department, exhibiting its greatest width at once at the northern portion and at the centre of the department. It is everywhere loftier than the primary chain, and its ramifications are likewise more numerous.

* See Journ. de Phys. vol. lxxxii. lxxxiii.

† Marcel de Serres sur la Constitution Géogn. du Dép. d'Herault.

The rocks of which it consists bear in many places evident marks of fusion, and are manifestly connected with the volcanic chain already described, which extends northwards through the department of Ardeche to that of Haute Loire and Cantal, terminating, as we have seen, in the district around the Puy de Dôme.

The only one of these rocks which it has fallen to my lot to visit is that of St. Loup, an extinct volcano close to the sea, about a league to the north-west of Agde, a town placed at a distance of about twelve miles west of Cette in Languedoc.

Its crater, which is of considerable size, has emitted two currents of lava, on one of which the town of Agde itself is erected; whilst the other, having taken the direction of the sea, has formed a neck of land, as well as a little island at a short distance from the shore.

Marcel de Serres seems to regard the rock of Montferrier near Montpellier as belonging to the same epoch and formation, but I found it to consist wholly of compact trap, and therefore regard it of much greater antiquity.

CHAPTER IV.

ON THE VOLCANOS OF GERMANY.

Volcanos of Germany.—Modern ones in the Eifel.—General characters—distinguished into those of the Upper and Lower Eifel.—Upper Eifel—Gerolstein—Mosenberg—Bertrich.—Lower Eifel—Lake of Laach—Lava of Niedermennig—Basin of Rieden and others.—Trass of Brühl—its origin considered.—Crater of Rodderburg.—Antiquity of the Eifel volcanos discussed.—Ancient volcanos—near the Rhine—Siebengebirge.—Quarries of Obercassel—Vogelsgebirge—Westerwald.—Basaltic knolls near Eisenach—Pflasterkaute—Budingen—Blaue Kuppe—Meisner—Habichtswald—Steinheim—Odenwald—Black Forest—near Freyburg—near the Lake of Constance—Wirtemburg—Rhöngebirge—Fichtelgebirge—Kammerberg near Egra—Toeplitz—Erzgebirge—Riesengebirge—Moravia—near Hof, near Banow.—General remarks on the Volcanic Rocks of Germany.

After this general description of the volcanos of France, I shall proceed to a short sketch of those which occur distributed over various parts of Germany.

Although active volcanos are not found in any part of that extensive country, and the recognition of those which are extinct dates only from the last century, yet no one familiar with this class of phænomena can return from a visit to their principal localities with any more doubt as to their former existence, than an American who had witnessed the burning mountains of his own hemisphere, but had never heard of those in Europe, would entertain with respect to the real nature of Vesuvius, if landed at its foot when it chanced to be in a tranquil state.

This remark applies to no case more completely than to that of the rocks which occur in a district commonly known by the name of the Eifel, situated between the Rhine and the present frontier of the Netherlands *.

This country is bounded on the south-east by the Moselle,

* This account of the Rhenish volcanos is principally drawn (where the reverse is not stated) from observations made by myself during a tour in that country in the summer of 1825.

on the north-east by the Rhine, on the west by the Ardennes and the other mountains round Spa and Malmedy, and on the south by the level country about Cologne.

The fundamental rocks which come to view are of a schistous character, and with their accompanying shales and sandstones, were styled by myself, in common with others who had described the district, *greywacke.*

Later observers, however, have spoken of them in a less vague manner, Lyell regarding them as constituting the inferior members of the carboniferous series, whilst Professor Sedgwick and Sir Roderick Murchison consider them as belonging partly to the Devonian and partly to the Silurian system.

It is at least certain, that the saccharoid magnesian limestone, containing trilobites, and other fossils of the same age, which is found associated with this formation, places it very low in the series of the palæozoic strata.

These rocks, in a few places, support horizontal beds of what appears to be the second or variegated sandstone formation. Scattered, however, over the greater part of the district alluded to, are a number of little conical eminences, often with craters, the bottoms of which are usually sunk much below the present level, and have thereby in many cases received the drainage of the surrounding country, thus forming a series of lakes, known by the name of "Maars," which are remarkably distinguished from those elsewhere seen by their circular form, and by the absence of any apparent outlet for their waters.

Steininger *, a geologist of Treves, who has published the most circumstantial account of the whole district that has yet appeared, distinguishes these craters into three classes.

The first includes those, properly speaking, known by the name of "Maars,"—volcanos which have ejected nothing but loose fragments of rock with sand and balls of scoriform lava. In this class are :—1. the Lake of Laach; 2. the Maar of Ulmen; 3. three Maars at Daun; 4. two at Gillenfield; 5. one at Bettenfield; 6. one at Dochweiler; 7. one at Walsdorf; 8. one at Masburck. Nos. 6 and 7, however, have fallen in.

* See, for an enumeration of his works, the Appendix.

The second class is distinguished from the preceding in consisting of those which have ejected fragments of slag, sometimes loose, and sometimes cemented together into a paste. Of this denomination are:—1. three craters at Gillenfield; 2. two at Bettenfield; 3. one at Gerolstein; 4. one at Steffler; 5. two at Boos; 6. one at Rolandseck.

The third class includes such volcanos as have given out streams of lava as well as ejections of loose substances. Of these latter we may mention:—2. two at Bertrich (one very small); 3. one at Bettenfield (the Mosenberg); 4. one at Ittersdorf; 5. one at Gerolstein; 6. one at Ettringen.

The above enumeration comprehends, probably, the most interesting of each class; but it must not be regarded as by any means complete, for Dr. Hibbert has added considerably to the list, within the limits of that district alone to which he has confined his attention *.

Geographically considered, these craters may be classified otherwise, as they belong to two districts, distinguished by the names of the Upper and Lower Eifel; the Upper lying to the south-west, in the angle between the river Moselle and its tributary the Kyll; the Lower Eifel near the western bank of the Rhine, extending to Mayence, where it is separated from the former volcanic district by the older rocks of the country.

The following description will apply to the volcanic formations in both these localities.

The sides of these craters, wherever their structure was discernible, appear to be made up of alternating strata of volcanic sand and fragments of scoriform lava, dipping in all directions away from the centre at a considerable angle; and the same kind of material has in many instances so accumulated round the cones, as to obliterate in great measure the hollow between them, and to raise the level of the country nearly up to the brim of the craters.

The formation of these cones seems likewise to have been, in some instances, followed by an ejection of substances of a pumiceous character, and the same kind of material (whether

* Hibbert on the Extinct Volcanos of the Basin of Neuwied on the Lower Rhine. London 1832.

derived from these or from some antecedent eruptions, will be afterwards considered) is spread widely over the country bordering on the Rhine, either in loose strata alternating with beds of a loamy earth, derived probably from substances in a minute state of division thrown out by the same volcano, and mixed up into a paste with water; or else forming masses of considerable thickness, in which the fragments of pumice are intermixed with the latter substance, and constitute together with it a coherent mass, known by the name of trass.

The volcanos of the Eifel are also, as above noticed, accompanied by streams of lava; but these have not, in my opinion, like the generality of those seen elsewhere, been satisfactorily traced to the craters, but seem rather to have flowed from the sides or base of the mountains with which they are respectively connected.

These *coulées*, like the volcanic cones themselves, are sometimes almost buried under heaps of matter subsequently ejected, so that in the lava of Niedermennig, the quarry, from whence the millstones are obtained, is worked at a depth of eighty feet from the present surface. They are in some cases analogous to the ejections of existing volcanos; but at others they possess more of a basaltic character, being freer from cells than true lavas generally are, although it can be demonstrated that they too are (geologically speaking) of modern formation, inasmuch as they follow the inclination of the valleys, and must therefore have flowed since the latter were excavated.

The above remarks may suffice for a general description of the Eifel volcanos. I shall now therefore proceed to particularise two or three of the more important, beginning with those of the Upper Eifel.

Upper Eifel.

The crater of Gerolstein is in itself one of the most curious in the series, and derives moreover an additional interest, as the spot which Von Buch selected for one of his proofs of the singular theory he has advanced, with respect to the conversion of common limestone into dolomite by volcanic agency.

The town of Gerolstein is built in a narrow valley between two ridges of limestone, each side presenting a precipitous escarpment, owing to the projection of occasional masses of the rock beyond the soil which covers in general the surface of the hill. This limestone is highly crystalline, and has all the characters of dolomite; it contains numerous corallines, together with trilobites, and other petrifactions belonging to the palæozoic series.

The slope of the hill fronting Gerolstein, like that at the back of the town, is wholly calcareous, but on reaching its summit we soon discover traces of volcanic operations.

If we commence our examination with the western extremity of the ridge which lies about half a mile beyond Gerolstein, we observe a conical mass of slaggy lava thrown up between the limestone strata, which are distinctly seen both north and south of it.

Connected as it would appear with this, is a mass of lava which occupies the centre of the western slope of the ridge, and may be traced to a considerable distance over the plain at its foot, divided however into two branches by a projecting mass of the calcareous rock which it meets with on its descent.

The cellular and even scoriform appearance of this lava, coupled with the manner in which it has accommodated itself to the present slope of the mountain, leads one to consider it a modern *coulée*; but I could not satisfy myself that it had proceeded, as is usually the case, from a crater.

There is indeed on the summit of the ridge from whence the lava proceeds, a little beyond the conical eminence above noticed, a crater-shaped cavity surrounded by volcanic matter, but with this the stream of lava seen on the slope of the mountain does not appear to have any connection.

Other patches of the same kind of rock, chiefly of a slaggy character, occur along the summit of this ridge east of the crater, which perhaps have been separately thrown up by a succession of small volcanic ejections unaccompanied by streams of lava. At the eastern extremity however of the ridge we are somewhat surprised to discover a small but abrupt knoll of compact basalt called the Casselburg, the site of a ruined castle, placed apparently under the same circumstances with the cones of scoriform lava before mentioned. It covers a bed of variegated sandstone which rests upon the dolomite, but the line of junction is so concealed with wood, that it is impossible to ascertain whether the basalt lies upon the contiguous rock, or, as is most probable, has been forced through it.

Von Buch, who had persuaded himself from some facts observed in the Tyrol, that dolomitic limestone derives its magnesia from the

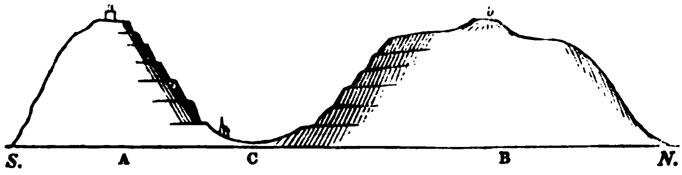
augite of lavas, appeals to its occurrence at Gerolstein in connection with so much volcanic matter as confirming the truth of his hypothesis*. But it seems difficult to reconcile this opinion with the age which we are compelled to assign to the volcanic operations here as well as in other parts of the Eifel. As it is evident that no foreign ingredient could penetrate the substance of the rock in its present hardened condition, so as to unite with the other constituents, and diffuse itself uniformly throughout the mass, it seems necessary for Von Buch's hypothesis to suppose the limestone to have previously been at least softened by the heat, which occasioned the sublimation of the magnesia. Hence we should be obliged to fix the period at which this process took place as antecedent to the formation of the valley, for this would be necessarily obliterated by any softening of the limestone which now overhangs it.

Indeed it would be necessary to carry back this supposed softening of the calcareous rock to some period antecedent to the retirement of the ocean, when sufficient pressure might be exerted to prevent the carbonic acid from being driven off from the limestone when exposed to the heat required for softening it.

But all this is completely contradicted by the phænomena of the volcanic products in question, the cellular appearance of which plainly indicates the absence of pressure, and which even seem, from their connection with a crater, and by the manner in which they have accommodated themselves to the present slope of the valley, to have been formed at a comparatively recent period.

The following section may serve to give a clearer notion of the relative situations of the rocks.

Section of the rock on either side of Gerolstein from North to South.



A and B are two hills composed of dolomite, and in the centre of B is the little crater *b*, consisting of slag and scoriæ. C, the valley in which Gerolstein stands, which would be filled up, if the rocks on either side had been fused or softened.

---

* Von Buch, Ueber das Vorkommen des Dolomite in die nahe der vulkanischen Gebilde der Eifel, in the 3rd vol. of Nöggerath's Gebirge in Rhinland Westphalen.

Mosenberg.

A few miles south of Gerolstein occurs another volcanic hill, called the Mosenberg, the structure of which is also very remarkable.

It constitutes a long round-backed eminence, on the edge of which, and but slightly elevated above the general level, are three craters, two of which are perfect, the third broken away on its southern extremity.

These craters, as well as the whole of the high ridge on which they stand, are composed of slag; but at the basis of the hill, just below the point at which the crater is broken away, is seen a mass of basaltic lava, very slightly cellular, which continues in an easterly direction for about half a mile. It has all the appearance of a *coulée*, and most writers have regarded it as derived from the crater which is broken away on the side nearest it. With regard to the latter point, I must confess myself not altogether satisfied, having failed in tracing the basalt up to the crater itself; and I am the more confirmed in my scepticism, because the ridge which it forms appeared to me to extend considerably west of the point at which it would have commenced, had it descended from the side of the crater which is broken away.

Among the phænomena connected with this mountain, not one of the least curious is the crater-shaped cavity called the Meerfeld, which lies at its northern extremity. It is perfectly round, and sinks regularly towards the centre, where is a small lake, so that its resemblance to the other "Maars" of the Eifel district is complete. On examining however its sides, we do not find a single trace of volcanic matter, the whole circumference of the hollow being composed of clay-slate *.

Viewed in connection with the surrounding country, it seems impossible to attribute it to any other than to volcanic agency, differing only from the other craters in its being caused by a disengagement of elastic vapours, unaccompanied by any ejection of solid matter.

* Dr. Hibbert (p. 24) understands me to assert in this passage, that no ejections of volcanic materials have taken place from this crater; whereas, he says, that balls of olivine derived from this source are in fact a peculiar characteristic of the volcano. My meaning however was, that the sides of the crater were composed of clay-slate, and this I believe to be the case; the occurrence of loose fragments of volcanic matter scattered about its sides would not affect my argument, and therefore was not noticed in the text.

Bertrich.

. The only other volcanic appearances I shall stop to particularise, are those exhibited near the Baths of Bertrich, not far from the road between Coblentz and Treves.

Bertrich lies in a narrow valley that has been excavated, in that great table-land of Silurian or Devonian slate, which occupies so large a portion of the district we are considering. To the north, just where the slope begins, we may observe a small conical hillock, called the Falkenlei, presenting a precipitous front towards the valley, but on the opposite side sinking more gradually into the table-land. It consists entirely of slaggy or cellular basaltic lava, the former variety constituting the upper, the latter the lower parts of the formation. At a little distance to the N.W. occurs another hillock, rising conically from the same table-land near the commencement of the valley, which differs from the Falkenlei in enclosing a small but regular crater. Divided from the above by a round hollow in the clay-slate formation, or more properly a circular enlargement of the valley, is another more considerable volcanic hill, called the Facher-höhe, situated likewise on the brim of the hill, but rather to the S.E. of the other eminences. This is also conical, and has a crater broken away on its southern side.

Thus these three volcanic knolls, together with two other less considerable ones, that lie betwixt the Falkenlei and the Facher-höhe, form a semicircle corresponding nearly with the figure which the escarpment of the table-land presents towards the valley of Bertrich. All of them lie very near the brow of the escarpment, whilst no vestige of anything of the same kind occurs in the valley below.

In the latter however we observe a large assemblage of volcanic products, but presenting a different character. They are all basaltic, with but few cells or cavities, whilst the cones above are chiefly made up of scoriæ, and contain basalt but rarely. The basaltic lava of the valley may be traced from the village of Bertrich, which lies near its southern extremity, almost continuously along the sides of the brook called the Issbach for upwards of a mile, but its thickness is greatest at a point where this brook is enlarged by another rivulet which flows into it from the west.

This point lies almost under that part of the escarpment of the table-land on which the Falkenlei is situated, and it would appear that two streams of basaltic lava meet about this spot, the one proceeding from the direction of the Facher-höhe, the other running more from the north-west, and having the appearance of being derived from one of the cones lying in that quarter. When however we attempt to follow the above *coulées* up the slope of the hills,

down which, on the above supposition, they must have flowed, we are immediately stopped by the extreme thickness of the wood, which clothes everywhere the sides of the valley. If we take the circuitous path which brings us to the summit of these hills, and examine the two volcanic cones, we discover no signs of a stream of lava having been derived from either. Nor do I think that geologists are warranted in inferring from analogy, that the basaltic lava has descended from these eminences, since we have already seen that an equal degree of uncertainty exists with respect to the origin of the other lavas in the Eifel country; and indeed if the basalt of Bertrich actually came from that quarter, its situation would probably be marked by a corresponding convexity on the slope of the hill, if not by its being destitute of the timber which is so abundant elsewhere.

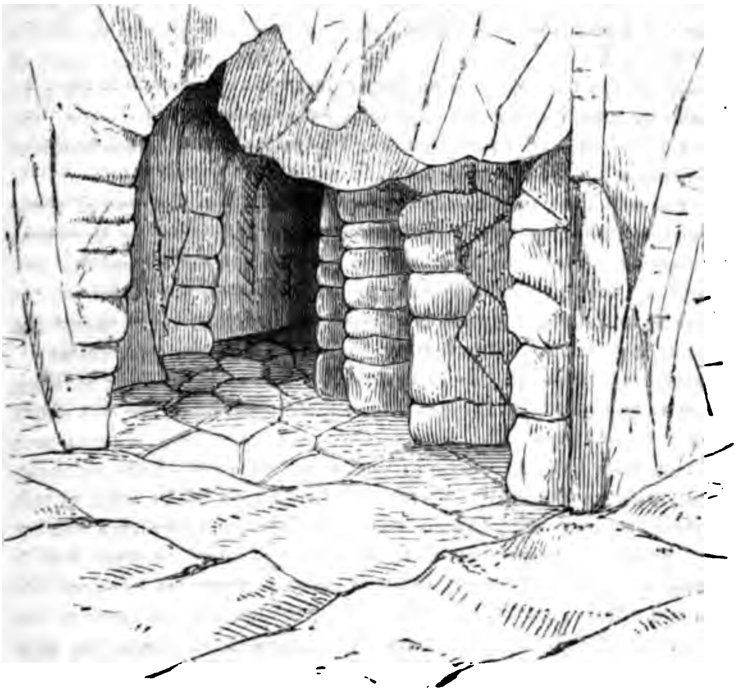
But whatever may be the fact with regard to the origin of these basaltic *coulées*, it is evident that they were formed since the excavation of the valley, inasmuch as they follow its inclination, and are not seen except near its bottom. They have however been cut through by the little stream of the Issbach which flows along the valley, and where that is the case, manifest a columnar structure.

At the point where the two basaltic *coulées* meet, an interesting fact occurs,—a natural grotto is seen in the midst of the lava about six feet high, three broad, and twelve or fifteen long, open at both extremities, and thus making part of a foot-path which overlooks the ravine containing the torrent of the Issbach. The walls of this grotto are composed of basalt, slightly cellular, and forming a number of concentric lamellar concretions, piled one upon the other, and in general somewhat compressed, so that the interstices between the balls are filled up. The grotto itself has obtained the name of the Cheese-cellar (Kase-keller), from the resemblance which the configuration of the basalt bears to an assemblage of Dutch cheeses; it beautifully illustrates the origin of the jointed columnar structure which this rock so often assumes, since a little more compression would have reduced these globular concretions into a prismatic form, each ball constituting a separate joint in the basaltic mass.

The most probable way of accounting for the existence of this natural grotto, is to suppose the lava which forms its walls to have cooled near the surface before the mass had ceased to flow in its interior; hence a hollow would be left in which the basalt had room freely to assume the form most natural to it, and the concretions, being but little compressed on account of the cavity within, retain their original globular figure. In further proof of this, it may be remarked that the lava above the grotto consists of irregular prisms, and not of balls, as is the case with that which constitutes its walls.

If it be asked, why the same appearances are not presented in Fingall's Cave and in others of the same kind, it may be replied, that the two cases differ, the Kase-keller being a hollow existing from the first, whereas the basalt at Staffa probably constituted a continuous bed until undermined and eaten into by the sea.

I am indebted to Professor John Phillips for the subjoined sketch of the Kase-keller, taken by him on the spot.



KASE-KELLER (BERTRICH) 1829.

Descending into the bed of the rivulet, we have an opportunity of observing the line of junction between the clay-slate and superimposed lava; on the former no change seems to have been effected, but there intervenes between it and the compact basalt which composes the mass of the *coulée*, a very thin stratum (perhaps not exceeding an inch in thickness) of highly cellular lava, a fact which may perhaps be explained by the extrication of steam from the damp surface over which the lava flowed, in the manner supposed by Sir G. Mackenzie with respect to some of the lavas in Iceland *.

Thus much for the basalt above the village of Bertrich; below it

* See the Chapter on that volcanic island.

occurs another isolated basaltic mass, which it would be even more difficult to refer to any of the volcanos on the hills above. It forms part of a low, oblong, round-backed hillock, rising in the midst of the valley, which is here somewhat wider than ordinary; the rest consisting of the clay-slate which seems to have been thrown up by the protrusion of the basaltic mass accompanying it.

The formation of this hillock has, if I mistake not, turned the stream of the Issbach aside from its original direction, and obliged it to cut a new channel which winds round the base of this little eminence.

The fact of the valley being larger just before we reach it than it is above, may I think be explained by supposing, that until the stream had created a new channel, the waters accumulated to such a degree as to form a lake, and the same may possibly have been the cause of the two other circular enlargements of the valley mentioned as occurring higher up. I have already had occasion, when speaking of Auvergne, to notice other cases in which lakes have evidently been produced by beds of lava obstructing the course of rivulets, and shall suggest this hypothesis as one of the modes of accounting for the formation of the Dead Sea, by supposing an obstruction caused in this manner in the bed of the Jordan to have been a consequence of the volcanic eruption that destroyed the cities in the vale of Siddim *.

The warm baths of Bertrich, and the carbonic acid which rises up in so many parts of the Eifel district †, imparting to the springs through which it passes the briskness of soda-water, are phænomena that seem to indicate a continuance of the volcanic operations formerly so prevalent—these however will be considered in another portion of my Treatise.

It would detain me too long were I to go through the description of other lake craters distributed over the Upper Eifel, although the geological traveller ought not to omit visiting the beautiful crater of Pulvermaar, and the three lakes at Daun.

Lower Eifel.

Let us next proceed to notice a few of the more remarkable features in the Lower Eifel, which borders upon the Rhine, and is known by the name of the Maifeld or Mayenfeld.

* See the Chapter on the Holy Land, where however facts will be stated that render the above hypothesis less plausible now than it appeared to me at the time of the publication of the first edition of this work.

† See Edinb. Phil. Journal, vol. xiii. p. 191.

The lake of Laach, near Andernach, is a large expanse of water embracing a circumference of two miles, and of an oval form.

Its sides are overgrown with wood from the level of the water up to the brim of the crater, which is reached externally by a gentle ascent not at all in proportion to the depth of the internal cavity.

The thickness of the vegetation renders it difficult to discover the nature of the subjacent rock, which seems however to be constituted of a black cellular lava full of augite. Besides this, the sides of the crater present numerous loose masses, which appear to have been ejected, and consist of glassy felspar, ice-spar, sodalite, hauyne, spinellane, and leucite. It will be seen, when I come to speak of the neighbourhood of Naples, how remarkable is the resemblance between these products and the masses formerly ejected from Vesuvius.

Dr. Hibbert* regards the lake of Laach as formed, in the first instance, by a crack caused by the cooling of the crust of the earth, which was widened afterwards into a circular cavity by the expansive force of elastic vapours. At the same time he supposes lateral fissures to have been produced in all directions round this central cavity by these forces, and in this manner to have arisen the valley of Brühl, and others in the vicinity of the lake, which from the precipitous nature of their banks appear to have been occasioned by disruption.

That this is a possible explanation I do not deny; but in what respect is it preferable to the notion that the hollow has been produced either by elevation or by subsidence?

Dr. Hibbert indeed states, that the former theory is inadmissible, because craters of elevation yield no streams of lava, whereas a trachytic current is observed to have issued from the crater of Laach. But this appears a misconception, for although an elevation-crater *may* be produced independently of any flow of lava, it does not therefore follow that solid materials cannot be afterwards ejected from the orifice; and if elastic vapours are capable of converting a longitudinal fissure into an oval cavity, I do not see why they might not have upheaved the rocks around a given area.

* History of the Extinct Volcanos of the Basin of Neuwied, 1832.

Nor, on the other hand, is the opposite theory of subsidence to be rejected as unworthy of our consideration, for it is quite conceivable that the existence of hollows underground, caused by the elevation of rocks in one portion of a district, may have produced a corresponding sinking of them in another, and that those craters which, like many in the Eifel country, are but little elevated above the general level, may have been caused by a failure of support underneath them.

The fragments of trachyte and of primary rocks which lie scattered around the margin of the lake, Dr. Hibbert attributes to eruptions which he supposes to have taken place at a later period either from the crater of Laach or from the hills immediately encircling it. The most considerable of these has given rise to the lava and scoriæ seen on the summit of a high ridge of clay-slate called the Veitskopf.

The many varieties of rocks, consisting either of trachyte or of granite, as well as of a character intermediate between the two, which have been ejected, give countenance, in Dr. Hibbert's opinion, to the notion I had advanced, that trachyte is merely a granite altered by volcanic fires. [This point however may be seen discussed with the advantage of the light derived from more exact observations, in the second chapter of this present edition.]

Towards the close of the tertiary period eruptions of basaltic slag and of black augitic sand began to cease in this district, and a new species of eruptions commenced, consisting of white pumice, which Dr. Hibbert supposes to have been chiefly ejected from fissures formed by previous volcanos amongst the hills called the Humrichs, south-west of Nieuwied, and to be derived from trachytic materials. Hence white pumice is very abundantly distributed over the country, even so far as Coblentz in one direction, and the valley of Brühl in the other.

Not much above a mile from this spot is the rock of Niedermennig, so extensively quarried for millstones; but though this has all the appearance of a stream of lava, no one has as yet succeeded in tracing it either to Laach or to any other neighbouring crater.

Steininger indeed imagines that it has arisen from a small

knoll, much concealed by verdure, situated about half a mile west of the town of Obermennig, and Dr. Hibbert suggests that it may have burst forth from some rent or fissure caused by those elastic vapours, which he supposes to have perfected the circular basin of Laach.

These however are merely conjectures, and the real source of the stream alluded to still remains open to investigation.

The lava is divided by vertical fissures into irregular columnar masses, some twenty feet in height, and these columns cut horizontally, and having their angles rounded off, are fashioned into millstones*, for which they are well-adapted from the unevenness of their fracture, derived from the infinite number of minute cells distributed through the substance of the rock.

It is only the middle portion however of this bed which can be so employed, for in the upper not only are the pores too considerable, but the concretions, being smaller than they are below, scarcely afford masses of sufficient magnitude for the purpose intended.

This difference arises from the greater size of the fissures which extend vertically through the substance of the rock; these, of considerable width at top, contract gradually as they descend, until they at length disappear altogether, and in consequence impart to the separate columns of rock a tapering form, gradually enlarging in bulk from above downwards, until the whole is at bottom confounded into one solid and entire mass.

Hence the rock of Niedermennig is distinguished by the workmen into three portions, which they compare to the top-branches, the trunk, and the root of a tree. The upper or top-branches† is that in which the columnar concretions are too small to be worth working; the lower or root, that in which the concretionary structure is lost by the final disappearance of the fissures; the central or trunk, that in which the columns are of a size adapted for millstones of the usual dimensions.

The lower part of the rock having never yet been penetrated, it

* The same use appears to have been made of the lavas of Etna by the ancients. See Corn. Sev. Ætna:—

Quin etiam vario quædam sub nomine saxa
Toto monte liquant; illis custodia flammæ
Vera tenaxque data est; *sed maxima causa molaris*
Illius incendi lapis, is sibi vindicat Ætnam.

† The upper portion is called *kopfe, glochen* or *aeste*; the middle *schienen* or *stamme*; the lower *sohlgestein* or *dielstein.* For these and other particulars, see Nöggerath über fossile Baumstamme, Bonn 1819, p. 60 *et seq.*

is impossible to state the exact thickness of the whole, but the upper portion not worked is stated at 7, and the central from 15 to 40 feet in thickness.

The lava of Niedermennig is interesting for the variety of extraneous substances imbedded in it. In the midst of the volcanic mass we observe not only hauyne, magnetic iron ore, and other crystallized minerals, but even portions of limestone, of quartz, or of an intermixture of quartz and felspar in the state of *kaolin*, which looks like the altered fragments of some granitic rock. The whole is buried at a depth of more than 60 feet from the present surface under a succession of strata consisting either of loam, the origin of which will be discussed afterwards, or of a congeries of rolled masses of pumice and scoriform lava together with those of all the different rocks found in the neighbourhood, the whole loosely bound together by a slightly coherent, loamy sand.

About three miles to the west of the lake of Laach is another circular cavity called the Basin of Rieden, which has much perplexed geologists, but which Dr. Hibbert conceives to have been originally a volcanic crater, from the interior of which cones of trachyte were subsequently upheaved, whilst beds of tufa were formed within the cavity by the ejection of pulverulent matters, which spread into the valleys and water-courses as far as Neuwied on the Rhine. Lastly, basaltic eruptions took place around the circumference of the basin, and either protrude through the tufaceous deposit alluded to, or have added to the height of the walls of the crater to such a degree as to have obstructed its drainage on the south-east, and to have caused the waters to discharge themselves in a new direction to the south-west into the ancient stream of the Nette.

Similar crater-shaped cavities, consisting of scoriform matter, and accompanied by cones of trachyte, occur in various other localities within the district bounded by the rivers Nette and Brühl. Small hillocks of slag also are here and there met with, and evidences of the ejection of basaltic matter may be also perceived in the cappings of many of the hills with that substance.

For these particulars however I must refer to Dr. Hibbert's Monograph, only remarking that although all these eruptions seem to belong to the tertiary period, a careful examination

distinguishes great differences in their age, and many successive periods of eruption in the volcanos of the district.

Throughout the neighbourhood of Andernach, in the low ground bounded by the Eifel mountains on the one hand, and those around Coblentz on the other, is found an immense deposit of trass or pumiceous conglomerate.

In no situation perhaps does it occur in a state of such development as near the village of Brühl, in the glen already adverted to, which meets at right angles the great longitudinal valley in which the waters of the Rhine find a passage.

The valley of Brühl seems originally to have been an excavation in the older rocks caused by some disruption of the strata, but it has since been partially filled up by an immense deposit of trass, which occupies its lower portion, but does not extend to the summit of the hills which bound it. This substance varies much in point of consistence at top and at bottom; in the latter situation being almost compact enough for a building-stone, whereas in the former it is more loose and friable. It contains imbedded fragments not only of pumice, but also of clay-slate, as likewise trunks of trees carbonized, and in one place even land-shells.

It has been observed that pumice in an entire state is most abundant on the right bank of the Rhine above Coblentz, about Engers, Neuwied and Bendorf, which agrees very well with what we should expect, if we suppose the source from whence it proceeded lay in the direction of the Eifel volcanos. The origin however of this substance has given rise to much discussion in Germany, and in particular between Professor Nöggerath of Bonn and M. Steininger*, to whom I have already alluded as the author of certain geological tracts on the country we are considering.

The former regards trass as the result of showers of ashes and pumice, which having fallen into water, became mixed

* See the elaborate paper under the title "Gibt Tacitus einen historischen Beweis von volkanischen Eruptionen am Niederrhein," by Professors Nees Von Esenbeck and Nöggerath, in the 3rd volume of the work entitled 'Das Gebirge in Rheinland Westphalen.' And for the arguments on the contrary side, the works of Steininger, especially his "Gebirgskarte, Mainz." 1822, p. 35.

up with the mud which that fluid was in the act of depositing, together with the fragments of the contiguous rocks carried down by torrents into the lowest situations; the latter, objecting to the above hypothesis, suggests that it may be possible to trace its existence to mud eruptions similar to those recorded as having occurred among the volcanos of Equinoctial America.

This hypothesis has been since maintained by Dr. Hibbert*, but the resemblance which the trass of the Rhine bears to the tuff about Naples, which will be afterwards considered, would lead me to assign to it the same origin.

Now it will be shown, when we proceed to this district of volcanos, that the tuff of the Neapolitan territory cannot be referred to any mere eruptions of mud, both from its vast thickness, and from the beds of shelly marl and limestone which alternate with it.

As however the rejection of one hypothesis does not imply the admission of another, it will be necessary to consider how far the opinion of Professor Nöggerath may be reconcilable with the situation and other phænomena of the trass of the Rhine.

I assume as an acknowledged fact, that this material is derived in part from comminuted masses of pumice, and similar felspathic substances ejected by volcanic action. When we look therefore at the country in the neighbourhood of the Rhine, especially near Andernach, we discover pumice in two

* Dr. Hibbert conceives the primary cause of the deposition of this tuff to have been the formation of a crater called the Lummerfeld, to the north of the tertiary lake of Gleis. This crater having been filled with water was converted into a lake, and during the continuance of the volcanic action became occupied with tufaceous mud derived from volcanic eruptions. Upon the breaking out of a newer and lesser crater on the same site, that called the Kunkskopfe, the mud was displaced and distributed over the neighbouring valley of Brühl. A new crater-lake was formed within the Kunkskopfe, in which a fresh accumulation of *moya* or mud collected. This in like manner burst its barrier, overflowed into the valley of Brühl, dammed up the waters which issued from the upper and lateral valley of the Brühl so as to reconvert it into a lake, and likewise did the same to the lateral valley of the Kehl contiguous. These lakes gradually gave way to the corroding action of mountain torrents, until at length they were converted into river-courses, through which the Brühl and the Kehl now find their way into the Rhine.

different states, either entering as one of the ingredients into the composition of trass, or constituting a congeries of loose fragments not united by any cement, which alternates in beds with a sort of loamy earth of the very same nature with that deposited at present by lakes or by rivers which flow through a soft stratum.

The first idea that suggests itself in order to account for this difference is, that the trass was formed from pumice deposited below the surface of water, whilst the loose fragments were ejected upon dry land; but the alternation of the latter with beds of loam is sufficient to prove that this distinction is not altogether admissible.

That since the retreat of the ocean, water must have covered the face of this country to a considerable depth, is evident enough, I conceive, from the existence of that extensive deposit of marl or *loess* which occupies the bottom of the valley of the Rhine from Basle to Cologne, the thickness of which often exceeds forty feet, although it is the most recent of all the strata, resting often upon the diluvium, and covered by nothing except vegetable mould. The nature of the shells that occur in it, which are the same with those found at present in the country, proves that its origin cannot be very remote; and its apparent identity with the loamy beds which alternate with the congeries of loose fragments, consisting chiefly of pumice, that occur near Andernach, tends to show, that at a period subsequent to the excavation of the valleys in general, a large expanse of fresh water occupied the lower situations in this part of Germany*. As however the water

* The origin of this "loess" does not properly belong to the subject of volcanos, but as it has given rise to much discussion, and involves considerations connected with the changes which the district may have undergone in comparatively modern times, I will here subjoin the explanation which Mr. Lyell, who has studied it minutely, suggests with respect to its occurrence, and which Mr. Horner adopts as the most rational that has been offered:—

"Instead of supposing one continuous lake of sufficient extent and depth to allow of the simultaneous accumulation of *loess* at all heights, and throughout the whole area, where it now occurs, we may conceive that subsequently to the period when the countries now drained by the Rhine and its tributaries acquired nearly their actual form and geographical features, they were again depressed gradually by a movement like that now in progress on the west coast of Greenland. In proportion as the

has not in these cases given rise to the deposition of trass, it seems necessary to refer the latter to some more ancient period where the circumstances of the case were so far varied as to occasion a different result.

These circumstances probably were, the greater depth of water under which the pulverulent materials were deposited, and at the same time a greater thickness of the mass accumulated, owing to which two conditions such a pressure was exerted upon the component parts as caused them to cohere, and in some cases probably to exert a kind of adhesive attraction one to another, by which a considerable degree of compactness and homogeneity of texture was communicated to the whole, such as we observe in many parts of the tuff.

To this view of the subject I know but of two objections, one, the presence in the trass of Brühl of land-shells similar to those at present existing, the other, its filling up a valley; but the former, being found only in one place, may have been washed there by rain or torrents at some subsequent period; and the latter circumstance, as has been already suggested, may have been produced at a comparatively early period by a disruption connected with volcanic agency.

If these suppositions be objected to as gratuitous, I would remark that they are proposed merely to reconcile the formation of the trass of the Rhine with that of the analogous formations of Hungary and Naples, which I shall afterwards consider, and to explain the fact of its occurrence in all cases underneath the *loess*, and never alternating with it, as is the case with those beds of pumice which exist uncemented by any paste.

This trachytic tuff therefore would seem to be antecedent in point of time to those craters existing in its neighbourhood or in the Upper Eifel, from which the uncemented pumice, seen at times alternating with or superimposed upon *loess*, was ejected.

But perhaps the most recent of the volcanic eruptions that

---

whole district was lowered, the general fall of the waters between the Alps and the ocean would be lessened, and both the main and lateral valleys becoming more subject to river inundations would be partially filled up with fluviatile silt containing land and freshwater shells."

has occurred in the whole district is that which produced the little hill of Rodderburg, bordering upon the Rhine and fronting the romantic island of Nonnenwehrt, a few miles to the south of Bonn.

This, though placed by the side of the Rolandseck, a hill consisting of prismatic basalt and of great antiquity, is itself composed entirely of slaggy lava, and contains a perfect crater.

According to a German geologist quoted by Mr. Horner, the highest point of the crater is 330 Rhenish feet above the river, its longest diameter 1000 paces, its shortest 700. It is seen to rest upon gravel. Fragments of greywacke and of quartz are common in the lava; they are found imbedded in it, and their surfaces are frequently vitrified. These vitrified pebbles are met with abundantly among the scoriæ on the sides of the hill, varying in size from a foot to the tenth of an inch in diameter. Volcanic bombs are occasionally found, and some which the author broke presented the following remarkable appearance:—

"These almost perfectly round balls, the largest of which might be about the size of a man's head, contained in the interior lapilli, small rounded portions of porous lava, vitrified and non-vitrified quartz pebbles, and small fragments of greywacke, some friable, others vitrified, and some unchanged. These bodies, which were of the size of nuts, filled the whole interior space of the bomb; they lay chiefly loose, often five or six were adhering together, or single ones were fixed to the sides of the bomb, so that by breaking the porous lava-shell, which was about a finger's breadth in thickness, great caution was necessary to prevent the contents falling out. In the interior of one of the bombs there was a small detached crystal of augite."

Recent however as this, as well as many of the volcanos of the Eifel appear to be, yet it is probable that, like the most modern of those in Auvergne, their eruptions were antecedent to all historical records at least, if not to the period at which the country was first peopled by man.

Steininger* and others indeed appeal somewhat absurdly

* The following is the passage to which they allude:—

"Sed civitas Juhonum, socia nobis, malo improviso afflicta est. Nam ignes, terrâ editi, villas, arva, vicos passim corripiebant, ferebanturque in

to a passage of Tacitus, which they interpret as referring to an eruption of one of the Eifel volcanos at so late a period as the reign of Tiberius Cæsar.

The historian alluded to notices, it is true, in his 'Annals,' a fire that broke out from the earth, and ravaged the country of the Juhones, extending even to the walls of Cologne.

This fire, it is added, could not be put out by water, and baffled every other expedient, until the inhabitants, finding that they checked it by volleys of stones, came near, and at length succeeded in smothering it by throwing heaps of clothes upon the flames.

The passage to which I have referred has given rise to the very elaborate paper by Professors Nöggerath and Nees von Esenbeck, published in the work before-quoted, in which it is shown, first, that there is no certainty as to the country which the people called by Tacitus "Juhones" inhabited, or whether indeed that be the true reading; secondly, that a fire which reached the walls of Cologne could not be volcanic, for no volcanic appearances exist within twenty miles of that place, the nearest crater being that of Rodderburg, just described; and thirdly, that the description of Tacitus applies much better to some artificial combustion, such as what might be caused by setting fire to the woods or heaths in a dry season, than to anything of a volcanic nature. It is indeed quite ridiculous to refer to any such cause a fire which was checked by volleys of stones, and stifled by throwing over it dirty clothes; and if we conceive ourselves obliged to adhere to the words of the historian, and believe the flame to have "emanated from the ground," it seems more likely that it should have arisen from a disengagement of inflammable gas, than from the usual concomitants of an eruption.

When however we recollect that at the period to which we allude, a colony planted at this distance from the seat of empire bore much the same relation to Italy which the back settlements of Canada or the wilds of Newfoundland do to Great Britain, it seems scarce an impeachment upon the general accuracy of the historian to suppose,

---

ipsa conditæ nuper coloniæ mœnia. Neque extingui poterant, non si imbres caderent, non fluvialibus aquis, aut quo alio humore: donec inopiâ remedii, et irâ cladis, agrestes quidam eminus saxa jacere, dein, residentibus flammis, propius aggressi, ictu fustium, aliisque verberibus, ut feras, absterrebant. Postremo tegmina corpori direpta injiciunt, quanto magis profana, et usu polluta, tanto magis oppressura ignes."—*Tac. Ann.* lib. xiii. c. 57.

that he may have been misled by popular rumour in the details of an event, at once so remote and so little affecting the general interests of the state.

Steininger in a subsequent publication has communicated another fact which he thinks conclusive as to the modern date of the trass about Bendorf, namely the discovery of a coin of Vespasian imbedded in the substance of the mass. Unfortunately however it turns out that Roman altars are preserved cut out of this very same rock, so that we must account for the presence of the piece of money, as perhaps it is not very difficult to do, from the action of rains or torrents washing down upon the coin a quantity of this trass, which afterwards became consolidated. We may also remark that Steininger did not find the coin himself, but received it from one of the workmen, whose account of its actual position cannot be greatly depended upon*.

It is also certain that the lava of Niedermennig existed in the time of Augustus, for the pillars of the ancient Roman bridge at Treves are built of this material†.

But though we are under the necessity of attributing to the

* See the memoir before alluded to in Nöggerath's 'Rheinland Westphalen.'

† It is curious that Becanus, in his 'Origines Antwerpianæ,' lib. i. p. 60, attributes the fire recorded by Tacitus to the combustion of some of the bituminous or coaly matter so common near Liege in the Netherlands: "Ubi sunt specus illæ subterraneæ, pigra barathra, montes piceo lapide sive Asphaltide constantes, et sylvæ obscuræ."

But this hypothesis is altogether irreconcilable with the statement of the historian as to the fire having reached the walls of Cologne, a city, which from its distance from Liege, as well as from the structure of the intervening country, must have been quite beyond the possible influence of such an event. Becanus likewise supposes, with not much more probability, that this was the spot referred to by Claudian as having afforded Ulysses an entrance into the infernal regions:—

Est locus, extremum quâ pandit Gallia littus,
Oceani prætentus aquis, ubi fertur Ulysses
Sanguine libato populum movisse silentûm.
Illic umbrarum tenui stridore volantûm
Flebilis auditur questus: simulacra coloni
Pallida, defunctasque vident migrare figuras.

Lib. i. Carm. 3. 123.

But those who consider the above passage as a sufficient ground for assuming the existence in Gaul at that time of appearances analogous to those of the Phlegrean Fields near Naples, will look to the volcanos of the Eifel district, and still more naturally to those of Auvergne, as their probable site, rather than to the coal country of the Netherlands.

Eifel volcanos a date historically very ancient, geologically speaking they are the most modern in this part of Europe, for the remaining rocks near the Rhine to which we attribute a similar origin, no less than those in Hessia and on the borders of the Thuringerwald, belong evidently to a more remote period. The latter indeed all appear to have been submitted to the same agents that have affected the older formations; their craters, if ever they existed, have been obliterated; the evidences of their destruction are seen in the rolled pebbles at their foot; and they are intersected by deep valleys, which evince at least the long-continued action of the causes that have produced them.

Yet it would appear that the Rhenish volcanos have been principally formed during the period at which the tertiary beds were deposited, for I know of no instance where they are covered by anything older than the gravel, or the loess, both of which may be regarded as alluvial, and in many cases they are seen to rest upon the brown coal formation.

The age of the latter does not appear to be as yet determined, but it is probably more recent than the period of the plastic clay, to which it had been referred. Organic remains of fish and of batrachians, both appertaining to extinct species, are found in it; and those which it contains of plants appear to belong to dicotyledonous trees and shrubs, bearing a close resemblance to those now existing in the country.

Mr. Lyell therefore places, although doubtfully, the Rhenish volcanos in the oldest Pliocene period; and to this epoch we may perhaps refer the rocks at the Habichwald near Cassel, those at the Meisner near Eschwege, in the Westerwald east of Coblentz, as well as in the Siebengebirge near Bonn.

Siebengebirge.

The latter chain of hills presents in some measure the general features of the whole, and shall therefore be noticed more particularly.

On the eastern bank of the Rhine, rising abruptly from the borders of the river, are the mountains which have obtained this appellation from the seven peaks which strike the eye at a distance. To the north they seem to sink more gradually into the plain; but on the south they terminate in the "castled

crag of Drachenfels," which offers on that side a very precipitous front.

This chain of hills consists for the most part of trachyte, but that rock is so often associated with basalt, or passes into a material so nearly allied to the latter, that we feel it difficult to admit with Beudant, that the two formations are produced by different processes and belong to distinct epochs.

I observed on the hills above Königswinter one instance, in which a dyke which penetrated the tuff obliquely, sending out horizontal branches from the main branch, consisted partly of trachyte, partly of basalt; and where, as often happens, the trachyte becomes charged with crystals of hornblende, it gradually passes into a black substance agreeing in its general characters very nearly with basalt.

Nevertheless, I do not dispute that the principal mass of the basalt in this district has, as Mr. Horner states, been erupted at a distinct and later period, dykes of it frequently traversing, not only the older rocks of the district, but likewise the tuff and even the trachyte, whilst there is no instance recorded of a trachytic dyke traversing basalt.

Moreover, the basalt has every claim to be regarded as a distinct member of the volcanic series, forming the three highest hills in the district, namely the Duisberg near Linz, the Oehlburg, and the Löwenburg in the Siebengebirge, whilst the extent of their united surfaces is fully equal to that occupied by trachyte.

We must distinguish, then, between the basalt which was ejected in large quantities, as an independent and *later* product of the volcanic operations, having spead over the surface equally of all the igneous and neptunian rocks of the district, and that which forms an integral part of the trachytic formation, and has all the appearance of being contemporaneous with the latter.

The former was ejected through the medium of dykes, which are seen everywhere intersecting the older rocks; the latter seems rather to have been heaved up in mass through thick strata of trass or trachytic tuff, which had been previously deposited.

That it is in this manner the Siebengebirge have been formed, appears probable from an examination of them on

the side that overlooks the river. We here may trace for some distance up the hill a micaceous slaty sandstone belonging to the so-called greywacke formation of the plain below, containing thin seams of anthracite. This is covered by nearly horizontal beds of a kind of trass, like that near the lake of Laach, but containing less pumice. On ascending to a greater height we meet at length with the trachyte, which seems therefore to lie under the other rocks, at the same time that it rises above them.

This trachyte is traversed by vertical fissures, as is the lava of Niedermennig, like which it is often cellular, and contains imbedded portions of a mixed rock looking like altered granite, but in which the felspar is changed into *kaolin*. The rock of Drachenfels consists of a somewhat different variety of trachyte, marked by its large and regular crystals of glassy felspar; and the mountain adjoining it on the west, called the Wolkenburg, differs from either, containing a number of minute acicular crystals of hornblende. It seems evident that these rocks have both been forced up through the palæozoic rocks, which indeed continue until we reach nearly two-thirds of the entire height of the Wolkenburg. They are covered by the same *loess* which I have before noticed.

Near Königswinter however we observe, lying betwixt the palæozoic rocks and the trachyte, a very compact quartzose conglomerate, which Professor Nöggerath has referred to the brown coal formation, seen so extensively on the western side of the Rhine. It is rarely observed so compact as in this instance, and it contains masses of opal in which the fibrous structure of the wood is plainly discernible. Thus the date of the trachyte is at least as recent as that of the brown coal formation.

The basalt of the Siebengebirge and its neighbourhood is frequently columnar and sometimes amygdaloidal from the presence of imbedded minerals, such as olivine, calcareous spar, and more rarely zeolites.

In these respects it is undistinguishable from the basalts of greater antiquity which occur elsewhere, but vesicular masses, in which the cells are not filled with any mineral matter, and possess a glassy appearance, are also to be met with in it.

Professor Nöggerath has described some interesting par-

ticulars which may tend to illustrate the general structure of the basalt in these localities, in his account of the quarries of Obercassel, at the southern extremity of the Siebengebirge.

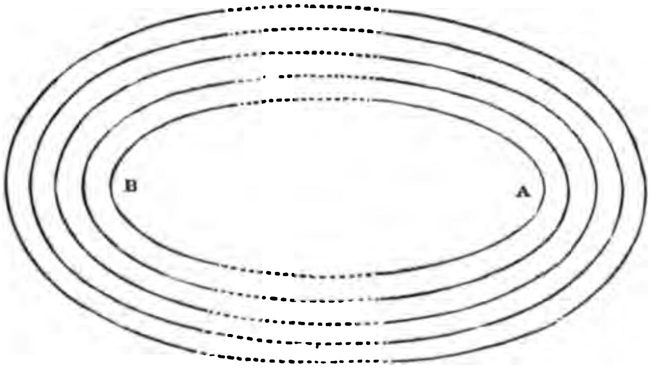
They are composed of basalt, which, though more commonly compact, is occasionally found vesicular, and the vacuities, which are generally oval, appear to be of the same age with the rock, and not to have resulted from decomposition. Some of them are filled with calcareous spar, carbonate of iron, and other minerals, but others are void.

The point however most worthy of notice in this rock, is the concentric arrangement of its parts.

The principal quarry, that of Ruckersberg, situated near the summit of the hill, displays this structure in the most satisfactory manner *. We observe here, not a cluster of globular concretions, like those of Bertrich, nor yet a line of prisms parallel to each other, as in many parts of the Vivarais, but a succession of concentric coats, which on the northern side of the rock are broken away, but in that which is entire are seen encircling one another in such a manner as to create an impression that the whole may have once formed an immense spheroid, composed of a series of laminæ wrapped round a common centre.

That the form of this mass was elliptical, having its longest axis in horizontal direction, appears from this circumstance;—that to the north of this quarry, but exactly parallel to it, another section of the rock is exposed, in which the same concretionary structure presents itself, but the laminæ form a portion of a curve turned exactly in the opposite direction to that of the former locality.

Thus, let A be the quarry of Ruckersberg, and B the section ex-



* See Nöggerath's Rheinland Westphalen, vol. ii. p. 250.

posed to the north of it, the following will be the disposition of the strata, from which it is evident that if the rock had not been broken away in the interval, an ellipsis would have been formed.

We observe too as we descend, that whenever a section is exposed, the direction of the strata is such as corresponds very well with this idea, the rock being found at a short distance below, dipping towards the same point, but at a slighter angle, and at the bottom becoming at length completely horizontal.

Now this admits of a ready explanation, if we suppose the whole mountain to have constituted the same great elliptical mass, since it is evident, that, agreeably with this structure, the dip of the strata would diminish progressively in proportion to their distance from the supposed centre, so that at length they would appear, when viewed within a limited space, altogether horizontal.

It is necessary however for this hypothesis, to assume, that the upper portion of the mountain has been swept away, since the axis of this immense spheroid is placed, not in the present centre of the mountain, but about the site of the quarry of Ruckersberg near its summit. Now as this quarry is about 300 feet above the base of the hill, we must attribute to the latter an original elevation of between 500 and 600 feet.

Besides this division into concentric laminæ, the basalt of Obercassel has likewise a tendency to form columnar concretions, which always range at right angles to the curvature of the strata; hence when the latter are vertically disposed, the prisms are horizontal, and *vice versâ*; appearing in every intermediate position in accordance with the dip of the laminæ themselves.

The *Seven Mountains* above referred to, although they may appear isolated, are in fact a prolongation of the extensive basaltic formation of the Westerwald, which is connected with another considerable volcanic district, north-east of Frankfort, termed the Vogelsgebirge.

From the latter, the isolated basaltic cones of Frankfort and Hanau on the one side, and of Cassel and Eisenach on the other, seem to be ramifications.

Different as these several chains may be to each other in various particulars, they have the following characters in common, by which, if I mistake not, they are distinguished from the basalts which occur associated with secondary strata.

Although frequently as compact as the latter, they are

always, when viewed on the great scale, found to be accompanied more or less with cellular products, the cavities of which do not appear to have ever been filled with infiltrations of crystalline matter, which is the case with the amygdaloids accompanying secondary basalt. These cellular rocks frequently occur on the highest parts of the chain, as near Rennerod in the Westerwald, where they rest on compact basalt, as though the latter had been the effect of the pressure exerted by the superincumbent stratum. In other places the compact basalt is seen on the highest portions of the chain, whilst beds of cellular lava occur mantling round it, implying that, after the formation of the central mass, ejections of cellular matters had succeeded, which ranged themselves round its sides. Such is the case in the Vogelsgebirge*.

The volcanos of the Westerwald are also identified with those of the Siebengebirge in consisting partly of trachyte†, and likewise in being accompanied with strata of trass, which seem to fill up the bottom of the valleys. Concerning the manner in which the latter has here been formed, I shall only remark at present that the existence in it of slag and pumice, as well as the rare occurrence of fragments of compact lava, like that of the mountains encircling it, seem to show, that it is derived in a greater degree from ejections of pumiceous matters, than from the detritus of the surrounding country.

Occasional knolls of basalt lie scattered over the whole space between the Westerwald and Vogelsgebirge, as at Limburg, Wetzlar, &c., which some may consider as the relics of a continuous stratum once covering the country, whilst others

* Leonhard, Basalt-gebilde, p. 112.

† Mr. Horner states in his Memoir, that the trachyte of the Westerburg had not been examined before Professor Mitscherlich's visit to it in 1832. It was noticed however by myself in 1825, though the only mention of it I had introduced into the first edition of my work was that comprised in the short sentence in the text. According to the Professor, it here covers a space quite equal in extent to the Siebengebirge, although not forming such elevated hills. In texture there is a great resemblance between the two, and it is accompanied not only by tuff, as I have stated, but likewise by clinkstone. It seems to be the only locality in Germany in which trachyte occurs, excepting the conical hills noticed in the Rhine province, and the Gleichenberg in Styria, which will afterwards be described.

may regard them as produced by distinct eruptions of volcanic matter.

That the latter is the true state of the case appears, I think, from comparing them with the conical basaltic hills near Eisenach, where circumstances have enabled us to ascertain clearly the relative position of the volcanic mass to the contiguous stratum.

As the latter appear to me highly interesting, not only in themselves, but also as affording a key to the structure of the whole country we are considering, I shall proceed at once to describe them, without noticing the rocks intermediate.

These knolls of basalt occur in the second or variegated sandstone formation, and appear on the surface to be perfectly unconnected one with the other. As they afford a valuable material for the roads, so much of them has in many cases been removed, that the rock which originally rose above the surface of the sandstone is now worked considerably below the level of the latter. In tracing it downwards the mass is generally found to enlarge, so that its shape appears to resemble that of a wedge.

The quarry in which the relation of the basalt to the contiguous rock is best exhibited, is the Pflasterkaute near Eisenach on the road to Frankfort*.

In this instance the excavations are carried to such a depth, that we are enabled distinctly to follow the basalt more than

* For a knowledge of this locality, and in some measure for the power of examining the geological phænomena therein displayed, I hold myself indebted to a very intelligent road-surveyor, M. Sartorius of Eisenach, who began many years ago taking advantage of his situation, to expose the rock in such a manner as might enable geologists in time to determine, whether the basalt merely lay upon the sandstone, as the Wernerians would suppose, or had been forced up through the midst of it from a considerable depth. His first account of this and other similar spots was published in 1802, in a small pamphlet entitled "Die Basalte in der Gegend von Eisenach;" but as every year's consumption of stone renders the excavations deeper, the fact must at present be exhibited in a more satisfactory manner than it was when he wrote his first pamphlet, it becoming more and more difficult to explain the position of the basalt by any irregularity of surface in the subjacent sandstone, as well as less likely that any termination will be found to the dyke as we penetrate downwards.

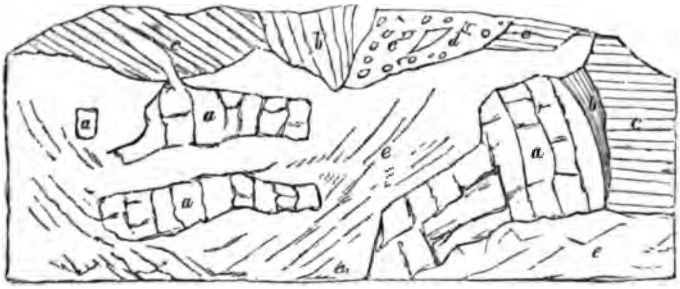
Sartorius has since published several other Geological tracts, which will be specified in the Appendix.

50 feet below the surface of the sandstone. The line of junction is also well-displayed, and we observe the sandstone, changed from a horizontal to a vertical position, split in all directions, and rendered harder and whiter, where the basalt touches it.

The latter is in some places compact, and in others cellular, in which latter case the cells are partly empty, and partly filled with calcareous spar, quartz crystals, and zeolite. The central portion of the mass is always freest from these hollows, and at the surface there is generally a kind of tuff made up of fragments of the volcanic rock cemented by clay or sand.

The following rude sketch, taken on the spot, may serve to give an idea of the relative position of the several rocks displayed in the quarry.

Vertical Section of the Pflasterkaute near Eisenach.



a a a a, Basalt. *b b*, Sandstone altered. *c c c*, Sandstone unaltered. *d*, Tuff with fragments of sandstone. *e e e*, Debris.

The Stoffelskuppe and the Kupfergrube, both which lie at no great distance, present similar phænomena, with this additional circumstance, that the masses of sandstone, which occur entangled in the midst of the volcanic rock, are sometimes prismatic. This last fact is however best displayed near the town of Budingen, north of Hanau, in the Wetterau.

The prevailing rock in this country is the new red sandstone, but on the slope of the hill south of the town occurs a little eminence called the Wildenstein, consisting of columnar basalt, which seems altogether isolated, being encompassed on all sides by sandstone.

Though we are not enabled here, as in the case of the Pflasterkaute, to observe the relation of the trap to the surrounding stratum, yet there can hardly be any doubt but that it was

forced up in the same manner, and has thus carried with it those portions of sandstone that occur in the very midst of the basalt.

These portions appear to have been curiously altered by the heat to which they were subjected; they are hardened almost to the degree of flinty slate, are rendered white and splintery, and in most instances form clusters of little prisms, possessing even greater regularity of form than those of the basalt which encircles them. It is curious to mark the resemblance between the prisms here alluded to, and those produced artificially in several parts of Derbyshire and Yorkshire*, where the soft friable sandstone of the country is rendered serviceable for road-making by exposure to heat, which hardens and causes it to split into small columnar concretions.

Sartorius has described a number of other basaltic eminences in the neighbourhood of Eisenach, all of which he supposes to have been thrown up in a similar manner, and many indeed of which are proved to be so constituted.

He likewise endeavours to show † that a connexion exists between many of these distinct cones, and that they are in certain cases grouped round some common centre, forming a system of basaltic eminences, which possess a degree of correspondence in position, and, as it should seem, in origin.

In the instance to which he appeals, the central point (the Dietrichberg) is a large overlying mass of basalt, the direction of which appears to be conformable with that of the subjacent rock; whilst in the smaller eminences of the same formation distributed round it, the basalt is always placed obliquely, and its inclination is found to vary according to its position with reference to this central mass.

Sartorius from thence concludes, that all these detached cones have been thrown up from a common point, and that the focus of the volcanic action lay immediately underneath the Dietrichberg, at a depth which he thinks might be calculated, by considering the distance of any one of these masses from the centre of the system, coupled with the degree of its inclination ‡.

* As at Rotherham.

† See Sartorius, Geognost. Beobacht. Eisenach, 1821, p. 100.

‡ He however admits the uncertainty of these calculations, for the depth

My principal motive for noticing this statement, which I had no opportunity of verifying, is to lead to an examination of other similarly constituted basaltic districts, with a view to ascertain whether any such arrangement or connexion can be perceived amongst them. At present all that I have stated must be understood to rest on the authority of Sartorius, to whose little publications I may refer for the most detailed account of these basalts, the igneous origin of which he has the merit of having maintained, even at a time when the authority of Werner was at its height.

But the rock perhaps which exhibits the greatest combination of phænomena calculated to shake any preconceived opinion with respect to the aqueous origin of these basalts, is the Blaue Kuppe near Eschwege, a town situated also in Hessia, but about twenty miles north-east of the above localities*. In this instance compact basalt is seen associated with a substance of so light and porous a description, in its nature so analogous to the productions of modern volcanos, that it would indeed argue an excess of scepticism to refuse attributing it to the same cause.

Unlike the other volcanic eminences noticed, the Blaue Kuppe consists on one side of sandstone, and on the other of volcanic matter, as if the force which caused the ejection of the latter had at the same time elevated the former. As in the Pflasterkaute, the sandstone here is hardened and cracked in all directions near the line of junction, and portions of it are everywhere imbedded in the substance of the basalt.

at which the volcanic force resided, appreciated by the obliquity of one of these masses, is 125,248 feet, or upwards of four geog. miles, whilst by another it would be only 79,104 feet. It is evident indeed that the inclination of the basalt is influenced by too many causes to afford any correct data for such an estimate.

* It is remarkable that Daubuisson, in his 'Account of the Basalts of Saxony,' never alludes to this mountain, although he seems to have particularly examined the Meisner, which lies no more than half a dozen miles off from it, and to which he appeals as affording evidence of the aqueous origin of trap. It would be curious to learn, whether this omission was the effect of accident or design; for the difficulty of accounting for the phænomena of the Blaue Kuppe on Wernerian principles suggests to us an explanation of his conduct more flattering, it must be confessed, to the prudence than to the candour of the geologist in question.

Besides the principal mass of volcanic matter occupying one entire side of the hill, are several dykes which penetrate the sandstone, enclosing portions of it, and altering its stratification in a very remarkable manner.

One of these appears to be a prolongation of the principal mass, but two others that occur a little on one side have no connexion with it on the surface. The upper portions of this rock consist of a sort of tuff composed of fragments of cellular and compact lava, intermixed with sandstone and cemented by wacke, whilst the nucleus is composed of basalt, which is sometimes cellular, but with the cavities for the most part filled with crystalline matter.

The quarry that has been made in this rock exposes a cavern in the midst of the volcanic matter, which serves still more fully to identify it with modern lava.

The basalt is here disposed in irregular strata, possessing a curvature corresponding with the arch of the cavern, and in its interior I found specimens of a more cellular variety of the same rock, which seems to have depended from the roof, like the stalactites, as they are improperly termed, of the caves in the island of St. Michael*.

A few miles north of the Blaue Kuppe† stands the Meisner, which not many years back was appealed to in proof of the aqueous origin of basalt, but which will probably now be viewed as affording additional evidence of the contrary hypothesis.

The basalt here forms an extended *plateau* overlying the new red sandstone formation; though in many places it does not do so immediately, there being here and there interposed a deposit of brown coal similar to that before noticed.

The latter is not only rendered columnar, as Daubuisson admits, near the line of contact with the basalt‡, but I am assured that it is also converted into anthracite. Daubuisson however contends that this alteration is not universal, and therefore that the incumbent mass can never have been in a

* See Dr. Webster's description of that island.

† There is a drawing of this mountain by Von Hoff, together with a complete description, in the Magazin der Berliner Gesellschaft Naturforschender Freunde, 5th year. An extract from the account may be seen in De la Beche's Geological Memoirs, p. 100.

‡ See Daubuisson on Basalt, translated by Neill, p. 204, note.

melted state,—an objection which will be best met in a future part of this work, when I shall have occasion to show that even modern lavas, in flowing over the surface of a rock, do not always produce any change upon it.

The basalt passes gradually into a granular substance, which may be called augite rock, consisting of felspar, augite, a little hornblende, and grains of titaniferous iron. All the upper part of the platform is composed of this substance, which differs from the basalt underneath only in the more distinct crystallization of its component parts *. This was also one of the circumstances appealed to by the Wernerians in proof of the aqueous origin of the rock, as it was conceived that such a crystalline structure would have been obliterated by heat †; and even Dolomieu was led by this consideration to admit the Wernerian doctrine with respect to greenstone. At that time the experiments of Sir J. Hall, Watt, and others, had not yet induced geologists to admit that crystals might, under certain circumstances ‡, have been the very result of the process which was at first imagined to be incompatible with their existence.

Near Cassel is a lofty ridge of mountains called the Habichtswald, which, including the Dornberg and other hills connected with it in character and position, forms a large square of about four German or twenty English miles to the west of that city.

It consists principally of beds of tuff, associated with scoriform lava and compact basalt, often containing nests of olivine, and the whole resting on a bed of brown coal, or where that is wanting, on freshwater limestone.

The basalt penetrates the brown coal in dykes and envelopes it, as it were, in masses varying from 4 to 100 feet.

The smaller of these masses are generally of a loose consistence, and are made up chiefly of tuff or conglomerate. They produce but little change upon the character of the brown coal, and are separated from it by a coating of clay.

The basaltic masses of from 10 to 12 feet in thickness consist

---

* The same association of greenstone and basalt occurs at Beaulieu in Provence. See page 43.

† See Daubuisson on Basalt. ‡ See my Fourth Lecture.

in the centre of compact basalt, but on the sides of tuff and conglomerate. Their influence on the brown coal extends for an inch or an inch and a half only. But when the basaltic mass approaches 100 feet in thickness, as in one instance is the case, the çoal is divided into prismatic masses near the point of junction, or is separated from it by the intervention of highly comminuted shining portions of the same. Further from the basalt, the coal is much fissured, and smells strongly of iron pyrites, which is found, along with green vitriol and selenite, pervading its mass. In some places the lignite puts on the character of glance coal.

The basaltic conglomerate is also in some places associated with plastic clay, and when this is the case, the latter is converted into polishing slate, containing impressions of fish, and indicating by its nitrogenous constitution the existence in it of animal exuviæ.

The tuff includes fragments of many vitreous and highly cellular varieties of lava, such as would seem to denote a recent origin compared to that of the trap rocks in the neighbourhood. Its structure is well displayed near the pleasure-grounds of the Elector, above the palace of Wilhelmshöhe*.

The hills above particularized may serve to illustrate the general structure of those numerous basaltic cones which lie scattered for a considerable distance on all sides of the Seven Mountains, the Westerwald, and the Vogelsgebirge, outliers, as it were, of that great volcanic formation, which in the latter places covers the whole face of the country.

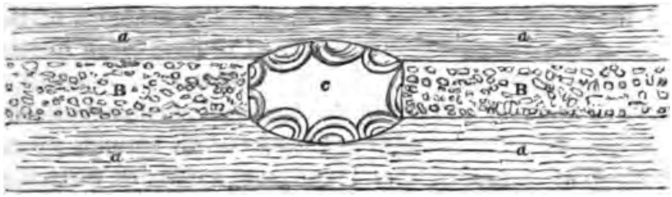
Other examples of the same kind are furnished by the neighbourhood of Frankfort and Hanau, where small wedge-shaped prominences of compact basalt, gradually becoming cellular near the surface, appear to have been thrust through the midst of the sandstone formation.

At Steinheim near Hanau the cells of the basalt are occupied by a variety of sparry iron ore, called by Haussman sphærosiderite, which forms a number of spheres varying from a line to an inch and a half in diameter, more generally quite compact, but sometimes hollow, and containing within a nucleus of a yellowish or ochreous matter, effervescing feebly with acids, and yielding with difficulty to the knife.

I observed some circumstances relative to this mineral and the rock containing it which seem to deserve a brief notice.

* See Raspe's account of some German Volcanos, London, 1776.

One was the occurrence of a sort of vein of cellular basalt passing through the substance of the compact, like the coarse-grained granite which we sometimes see penetrating a fine-grained variety. In the midst of the cellular portion was a cavity filled with the spathose iron above-noticed, as in the sketch underneath, where *a a* are the portions of compact basalt; B B those which are cellular; C the cavity with sphærosiderite coating its walls.



Another circumstance which I remarked, was, that the external surface of the spheres had in some cases a covering of white calcareous matter, in a powdery form, sprinkled over it.

The third observation I made indicated still more strongly that the whole had been in fusion, namely, the spheres being sometimes found flattened at the points where they appeared to have been in contact with the lava,—an effect arising in all probability from the contraction that took place in the surrounding parts whilst undergoing cooling.

Semi-opal also occurs between the interstices of this same rock, and I have even seen specks of noble opal disseminated through its substance.

The basalt, both near Frankfort and near Hanau, shows a remarkable tendency to concentric arrangement, and as it contains much iron, which becomes readily oxidized, the external layers decompose and peel off, leaving only a small nucleus of compact basalt retaining its original characters. In some cases the cellular and compact basalt occur intermixed, but in others the former is confined to the superficial portions. The cells, however, in these instances do not form that sort of network which is usual to them, but constitute long cylindrical tubes distinct from each other, just such as would be occasioned by bubbles of gas forcing their way upwards through a soft pulpy substance.

Enough has already been said respecting the general structure of the Westerwald and the Vogelsgebirge, which appear

to be composed of extensive plateaus and cones of basalt, covering the rocks of the country, but never alternating with them. Nor is there much to be learnt with regard to the manner of their formation by examining the districts themselves; and we might conceive a Wernerian of the old school, if he were to overlook or explain away the occurrence of cellular products amongst them, persuading himself that the whole was the result of aqueous deposition,—the evidence of that return of the waters, which is supposed to have given birth to the newest flœtz trap formation of his master.

When however we turn to the dykes of basaltic matter (as they may be called) which are scattered all around, we can hardly help imagining that these more extensive formations of the same rock have, in reality, been produced in the same manner—that the more elevated masses, which are generally most compact, were first thrown up by the agency of a volcano—and that the cellular matters, being subsequently ejected, arranged themselves around them in successive strata. The volcanic operations, taking place with the greatest intensity round the area now occupied by the Vogelsgebirge and the other basaltic groups, would completely cover with their products the surface of the subjacent rock; whilst at a greater distance from the sphere of their activity, isolated cones of basaltic matter might be occasionally thrown up, as at Eisenach, at Cassel, in the neighbourhood of Frankfort, and on the west bank of the Rhine.

Besides the volcanos above enumerated, there occur near the borders of the Rhine, but higher up the stream, other rocks which are considered to have a similar origin.

In the Odenwald, a group of hills in the neighbourhood of Heidelburg, rise from the midst of the new red sandstone some eminences, in which basalt is associated with augite rock (dolerite of Brongniart), and contains nepheline (Katzenbuckel), mica, mesotype, olivine, and titaniferous iron ore. The rock itself is probably analogous to that of the Hessian basalts. That containing augite is seen *in situ* at Gaffstein, whilst the one in which olivine is present occurs at Pechsteinkopf and Durkheim*.

* See Leonhard, Taschenbuch for 1822.

Near Freyburg in the Brisgau is the group of the Kaiserstuhl, of which Dr. Boué has given an account in his memoir on the South-west of France *. It appears from his report to be a mass of augite rock with excess of felspar (dolerite felspathique) thrown up from the midst of the plastic clay.

The highest mountain in the group is the Kaiserstuhl, which rises to the height of about 1120 feet above the river, and this with the other eminences composed of the same materials is ranged in an elliptical form round a valley.

These rocks offer no trace of craters or streams of lava, the volcanic force having only heaved up masses which it had previously brought into a soft or plastic condition, rendering them likewise slaggy at their surface; whilst at the same period the many smaller and lower knolls which occur at Old Brisach and Mohlberg were elevated from beneath. The cellular portions contain calcareous spar and mesotype, and hyalite occurs both within the cavities, and incrusting the surfaces of the rock. Tufaceous matters are not common, but they occur along the Rhine at Brisach, where they seem, like those near Eisenach, to be contemporaneous with the dolerite.

I am also assured that the rock of Kaiserstuhl is partially covered with a calcareous deposit, the only instance I believe among the Rhenish volcanos in which this association occurs.

Saussure †, who visited this group in 1794, and who appears to have been somewhat swayed by the authority of Werner, is nevertheless compelled to acknowledge the volcanic origin, both of the rocks about Limburg, which are in part penetrated with oval cells, in great measure void, and of the tuff about Echardberg, which contains fragments of scoriform lava. The origin of the basalt itself he considers doubtful; but few at the present day will concur with him in that opinion, considering how intimate appears to be the connection between the porous and compact rocks in this locality. Upon the whole, the group of the Kaiserstuhl may be set down as belonging to the same æra as the basalt of the Westerwald and the trachyte of the Seven Mountains, having been protruded during the latest tertiary period.

A few miles to the north of the Lake of Constance is the

* Annales des Sciences Naturelles, August 1824.

† Journal de Physique, vol. xliv.

commencement of another series of basaltic and porphyritic cones, first seen at Hohentwiel and in several detached hills contiguous, which rise from the midst of the (Jura?) limestone formation.

They consist in part of clinkstone and in part of basalt, accompanied with tuff containing fragments of trap rock (always compact) as well as of gneiss, limestone, quartz, &c., all cemented by a wacke-like paste of an ochreous colour.

In the hill of Magdeburg, a passage is said to exist between the clinkstone and the basalt*; at Hohentwiel, the former contains veins and nodules of natrolite, together with opal, pitchstone, and hyalite.

In Wirtemburg basalt occurs, both in overlying masses and dykes, in various places along the chain of the Rauhe Alp south of Tubingen, being perhaps connected with the rocks of Swabia above-described. Professor Scubler† remarks, that the horizontal stratification of the limestone composing that country is destroyed, wherever the basalt approaches it.

The chief localities are Linsenhofen, Faisel, Dettingen, Jusiberg near Urach, Grabenstetten, Donstetten, the valley of Guttenburg, Rauberstege near Brachen, and the neighbourhood of Dottingen, Offenhausen, Ehningen, and Donaueschingen.

Basaltic rocks, many of which are probably referable to the same class as those already noticed, appear to be scattered over many parts of Germany, especially the skirts of the Thuringerwald, the Fichtelgebirge, the mountains of Saxony, and the Riesengebirge of Silesia. Of these I shall bring together a few particulars, though the information I have been able to glean concerning them is scanty and imperfect.

The Rhöngebirge, a chain of mountains east of Fulda, appears to be a continuation of the same overlying formation which constitutes the Vogelsgebirge, and is seen in so many other parts of Hessia.

* See for this and other particulars a Memoir in Leonhard's Taschenbuch for 1823, by the Oberbergrath Selb.

† The Wirtemburgischer Jahrbucher for 1824 contains an account of these basalts, and an extract is given from it in the Bulletin des Sciences for November 1825.

Of this district I have seen no account of more modern date than that of Voigt in his work entitled 'Beschreibung des Hochstifts Fuld,' published in 1783, except a few short notices by Dr. Boué and Professor Leonhard.

The former writer speaks of the whole country as indicating volcanic action, containing in most parts rocks of basalt and of clinkstone porphyry (hornschiefer).

South-east of Fulda is a circular cavity which he considers to have been a crater, and which is full of water, like the *Maars* of the Eifel district. It is closed in by two hills, which meet towards the east, but on their western extremity leave an aperture in which the hollow called the crater is found. The first of these hills, called the Euben, is composed of what Voigt denominates lava, probably a scoriform or amygdaloidal basalt; the second, the Pferdekopf, of porphyry slate, which seems to have been forced through the former. The sandstone rock adjoining is hardened and otherwise altered, and where the lava is in contact with it, there is an intermixture between the two.

Dr. Boué, in his memoir on Germany, notices the passage of this same clinkstone rock into a kind of pearlstone at Heldburg near Coburg.

From this account of Voigt's one should be led to conjecture, that some of the volcanic rocks of the Rhöngebirge are of a very recent geological date; but as I am not aware that the statements of this geologist have been confirmed by any more modern observer, his report must be received with some mistrust.

The example indeed of Faujas St. Fond, who saw traces of craters in the basaltic rocks of the Hebrides, ought to render us cautious in receiving the accounts given by geologists of this school, at a period when every volcano, of whatever age, was imagined to have been formed after the model of Etna and Vesuvius.

On the north-eastern limit of Bohemia at the foot of the Fichtelgebirge occurs a series of basaltic cones, extending from Egra to Parkstein.

The most remarkable of these is the Hoher Parkstein near Weiden, which rises through the midst of the Keuper, and is marked by its isolated position, as well as by its conical form

and greater altitude, from the other hills in its neighbourhood. On the southern and south-western slope basalt crops out in fine columns, but in the other sides conglomerates and tufaceous-looking masses prevail, which also extend to the summit.

Now the fact of the elevation of these volcanic rocks through the Keuper sandstone is confirmed by finding imbedded in the midst of the basalt angular fragments of various sizes, from that of a hempseed to one of six or eight inches in diameter, which by their violet or lavender-blue colour are contrasted with the black matrix in which they are imbedded. A careful examination distinguishes in them portions of felspar and granules of quartz more or less fused and united to the matrix, although the line of junction is generally well-defined.

Beds of clay, and even of a fine-grained sandstone, appear to alternate with those of the basalt.

Other localities in the same range where basaltic rocks may be seen are, Neustadt am Kulm, Kemnat, Kulmain, Friedenfels, and five different spots between the villages of Waldsassen, Redwitz and Witterstein.

These however are volcanic rocks of probably great antiquity, but in the immediate neighbourhood indications occur of igneous action belonging to as recent a date perhaps as those which I have described existing in the Eifel, for near the town of Egra the little hillock of Kammerberg presents a specimen of the smallest volcano, as Berzelius says, of its kind in the world. This locality attracted also the notice of Goëthe, who has given a description of it in his 'Morphologie.'

On approaching it in a westerly direction we find ourselves at the foot of a very hard irregularly-divided basalt, which rises about twelve feet from the ground. Its direction is vertical, but is from time to time concealed by slags and earth. The basalt becomes more and more porous and cellular from below upwards, until at the summit of the Kammerberg it passes into a perfect slag, respecting the origin of which there can be no question, more especially as it incloses numerous clusters of olivine.

Here too is a small level surface where the supposed crater, a circular hollow, is found.

On the eastern side of the Kammerberg a small section has been made in it for the sake of constructing a path. On its perpendicular

side are numerous beds of earth of different thicknesses, dipping downwards at an angle of from five to seven degrees, and consisting of a great variety of rocks rendered scoriaceous by fire, between which beds of a different kind appear, the latter without doubt formed by water and deposited by the same.

That the slaggy and basaltic mass which constitutes the eastern portion of the Kammerberg has been thrown up from below is shown by the many fragments of mica-slate entangled in the slag, which are not at all rounded, and are evidently brought up from below. Many of these fragments in colour and form are quite unchanged, although enveloped in slag which has undergone fusion;—others are brittle, and apparently roasted by the heat. The quartz is least altered, and is only reddened superficially. Lastly, large fragments of mica-slate, some of which might be mistaken for rolled and transported blocks, and others having a glassy coating, are met with amongst the heaps.

The subject of hot springs will be considered afterwards, but I cannot refrain from reminding my readers that those of Carlsbad are situated in the immediate vicinity of Egra, and therefore within the influence of the volcanic *focus* which manifests itself in the Kammerberg.

From Egra to Toeplitz, and from thence to the Riesengebirge in Silesia, a chain of basaltic and clinkstone hills appears to extend in a direction nearly parallel to that of the primary range of the Saxon Erzgebirge.

Near Toeplitz in Bohemia, celebrated for its thermal waters, basalt and clinkstone, as in the vicinity of the lake of Constance, occur united, clinkstone forming the lofty conical hill of Bilin, in which fragments of gneiss occur surrounded by the volcanic matter. Beds of tuff alternating with tertiary limestone appear in the neighbourhood.

I examined this spot in 1820, but in too superficial a manner to speak confidently with respect to the age and character of the rocks; I believe however that they will be found to belong to the class of tertiary volcanos.

Dr. Boué states in his memoir on Germany* that scoriæ occur at Frietland in the Mittelgebirge, as likewise in the circle of Pilsen, at Wolfsberg, and at Salesel, where they contain leucite†.

* Journal de Phys. for 1822.

† Boué's Geogn. Gemalde von Deutschland.

A similar series of basaltic cones occurs likewise on the Saxon side of the Erzgebirge, from the neighbourhood of Schwartzenburg on the south-west, to the hill of Stolpen beyond Pirna on the north-east*.

Under various shapes, as in platforms, cones and domes, basalt forms the summits of about twenty mountains, some of which are isolated, others connected below with the neighbouring mountains, the basaltic cap alone remaining separate. It constitutes the highest points in the country, and principally occurs near the ridge of the primitive chain. Not being aware of the occurrence of scoriform matter in any of these localities, nor of their being incumbent on very recent deposits, I should have omitted all mention of them as unconnected with the immediate subject of this treatise, had I not been desirous of rendering as complete as possible my enumeration of the basaltic formations of Germany.

The localities mentioned by Daubuisson are, 1. the mountain called Schiebenburg, 1000 to 1300 feet in height, celebrated for that apparent passage of wacke into clay on the one side, and into basalt on the other, which was long appealed to in proof of the aqueous origin of the latter rock; 2. the Pœhlburg, near Annaberg, consisting of columnar basalt resting on gneiss; 3. the Bœrenstein, six miles to the south of Annaberg; 4. the Spitzberg, a peak consisting of mica-slate capped with basalt, 4000 feet above the level of the sea; 5. Heidelburg, near Seiffen; 6. Lichtewalde, on the frontier of Saxony and Bohemia, 3000 feet high; 7. the Steinkopf, consisting of gneiss, capped by syenite-porphyry, covered by a small platform of basalt; 8. Geissengensberg, near Annaberg; 9. Luchauerberg, south-west of Dippolswalde; 10. Cottauer-spitze, a cone of basalt resting on sandstone; 11. Heulenberg; 12. Winterburg, near Schandau; and, on the eastern side of the Elbe, 13. the remarkable columnar basalt of the Stolpen, which is incumbent on granite.

Besides these there occurs between Dresden and Freyburg a basaltic eminence, called the Landberg, where the fundamental rock is gneiss covered with clay-slate.

In all these cases it may be remarked that the basalt exists as an overlying mass, and never alternates with the other rocks of the country, so that Werner was fully borne out in his position as to its constituting a distinct class of rock formations; he seems also to have been warranted, in the then existing state of knowledge, in

* See Daubuisson on Basalt.

asserting that there was nothing in the characters of the substance itself, or in the minerals associated with it, as found in Saxony, which stamps it as the product of fire; and he might be excused, considering the vague descriptions of geological phænomena given by travellers at the time he commenced his career, in framing a system without reference to their statements; but he cannot be so well exculpated for his obstinacy in adhering to the same erroneous conclusions in spite of the evidence afterwards brought together in contradiction to them, and that even by some of the most eminent of his own disciples, such as Humboldt and Von Buch, who seem to have deviated more and more widely from the creed of their master in proportion as their acquaintance with volcanic phænomena became more extended.

If we follow into Lusatia the chain of the mountains of Saxony, we find that many of the eminences are capped with basalt, presenting there the same characters and relations as it does in Saxony*. The only difference to be observed is, that in the latter country the basaltic hills are situated near the summit of the mountain ridge, whereas in Lusatia they are placed nearer to its foot. One of the most considerable indeed, the Lanscrone, near Gœrlitz, a conical hill near 1000 feet in height, stands entirely isolated in the plain, and at a distance of about six miles from the mountain-chain.

In the Riesengebirge of Silesia, which may be considered a sort of prolongation of the Saxon chain, the hill, called the Kleine Schneegrebe, is on its north-west side composed of basalt, which appears to have been protruded through the midst of the granite forming the remainder of the hill†. In one part huge fragments of this rock are entangled in, and cemented into a compact mass by, a basaltic paste, the whole forming a singular species of conglomerate. The basalt is amygdaloidal, and contains zeolite and mesotype. It attains to the height of 4661 feet above the sea.

Von Buch, in his description of the environs of Landeck in

* See Daubuisson on Basalt, English translation, p. 73.

† Singer in Leonhard's Taschenbuch, 1823; and for the Wernerian view of its formation, Daubuisson on Basalt, p. 235, English translation. Professor Jameson is there said to regard it as an "upfilling," that is, he considers its position as dependent upon the irregularity of the granitic surface in that part.

the county of Glatz*, has noticed four basaltic hills superimposed on primitive rocks, the most considerable of which is the mountain of Deberschaar.

It also appears from the late work of Œynhausen on the Geology of Upper Silesia, that a numerous series of isolated basaltic cones extends from the Oder at Fachenburg to Troppau, and from thence to Freudenthal in Moravia †.

A few miles south of the latter place, but north of Olmutz, is the little town of Hof, near which, in the chain of hills called Gesenke, occurs a volcanic mass which exhibits indications of a more recent origin.

The following account of it is extracted from a German periodical work called the 'Hesperus' for January 1821.

The hill called the Raudenberg, which is situated to the south-east of the village of that name, is 2250 feet above the sea, and composed, together with basalt, of reddish, greyish,

* Min. Description of the environs of Landeck by Von Buch, translated by Dr. Anderson. Edinburgh, 1810.

† The following are a few of the details given by the author quoted in the text.

Between Michelau and Falkenburg basalt crops out of alluvial soil.

Between Troppelwitz and Jagerndorf are the basaltic cones of Schönweise; near Troppau those of Stremplowitz and Ottendorf; both amongst transition slate and greywacke.

The basalt of Kohlenberg lies amongst primitive slate.

Basalt also occurs between Tillowitz and Schiedlow, south of Falkenberg, and near Raklo.

Basalt blocks are found near Lipten.

At Annaberg is a basaltic cone 1300 or 1400 feet high, the loftiest eminence in the district.

A basaltic hill called the Mulwitzberg extends between the towns of Michelau and Falkenberg; the basalt is prismatic, contains little olivine, but much steatite. On the sides are blocks of a quartzy sandstone, perhaps tertiary.

Near Schönweise, not far from Jagerndorf, are two cones of basalt, surrounded by slate-clay, passing into transition conglomerate.

South of Troppau, at Ottendorf, basalt is met with in a transition country.

North-west of ditto, at Stremplowitz, are cones of basalt partly porous.

Between Bennesch and Raudenberg, is basaltic tufa containing augite, constituting a building-stone much like the lava of Andernach.

At Kohlerberg, south of Freudenthal, occurs a basaltic amygdaloid, containing quartz, calcareous spar, chalcedony and chlorite. It resembles the basalt of the Buchberg near Landshut, and is the nearest point to the primary range at which basalt is found.

or blackish scoriæ, which look as fresh as those of the Puy de la Nugère, or of Vesuvius.

These products inclose fragments of granitic rocks, and of mica or clay-slate, which are much altered, and seem to pass into the scoriform mass enveloping them. To the south-east of this hill, near Heydenpiltsch, are two hillocks of compact basalt; more to the south, near Brochersdorf, is a basaltic hill called the Saunikal; and on the right of the Mora river, near Friedland, are two others. To the north-east are two funnel-shaped cavities, of which the largest is seventy-five feet in breadth and eighteen in depth.

These basalts rise from the midst of mica-slate, are compact and sometimes columnar, and contain olivine.

Lastly, on the western border of Moravia, near the frontier of Hungary, is a small igneous formation near Banow, described by Dr. Boué in the geological memoir on Germany above noticed.

He represents it as a cone of grey clinkstone, containing crystals of hornblende, and having the few pores distributed through its substance elongated in a vertical direction. On its western side it incloses portions of hardened clay and sandstone of various colours, and on its eastern side it has thrown up and cracked in various directions a very large mass of the same kinds of rock, which have also become indurated where in contact with it.

Thus it would appear, that on either side of the great primary chain which passes through the centre of Germany, the several parts of which are known under the names of the Thuringerwald, the Fichtelgebirge, the Erzgebirge, the Riesengebirge, &c., there occurs a line of basaltic cones, which, though detached one from the other, are so placed as to indicate a certain mutual connexion. This notion respecting them is confirmed by observing that similar formations occur chiefly at a certain distance from these primary ranges, for Von Hoff has remarked*, that if one line be drawn from Upper Lusatia to Kulmbach in the country of Bayreuth, and another from the same point in a north-westerly direction, so as to pass through the towns of Eisenach and Munden, no

* See De la Beche's Geological Memoirs, p. 100.

basaltic rock is to be met with north of that line, notwithstanding the abundant occurrence of it to the south.

The same author has further shown in another of his publications* that the shocks of earthquakes are most common, in the same direction as that of the basaltic masses themselves, and round a certain distance on either side of the line in which they occur.

The importance of these observations will be more clearly perceived, when it has been shown that rocks indisputably volcanic are placed in the same linear direction, as it will add one to the series of proofs by which the origin of trap rocks is connected with that of modern lavas.

* Geschichte der Veranderungen der Erdoberflache, vol. ii., an excellent work, which has led me to refer to several writings, in the German language especially, that might otherwise have escaped my notice.

CHAPTER V.

VOLCANIC ROCKS OF HUNGARY.

Volcanic rocks of Hungary.—General description of the country.—Five varieties of the Trachytic formation found in it—1. Trachyte, properly so called—2. Trachytic Porphyry—3. Pearlstone—4. Millstone Trachyte—5. Pumiceous Conglomerate—re-united—rendered aluminous.—Theory of the formation of Alum.—Other minerals found in the Trachyte.—Synopsis of the Genus Trachyte.—Analogous formations in other countries and in Hungary itself, such as Felspar Porphyry.—Basaltic rocks in Hungary.

One of the most remarkable countries in Europe for the scale in which volcanic operations have taken place, the more so indeed because it lies at a great distance from the sea, and therefore, as we shall find, in a position the most opposite to that which recent volcanos usually affect, is Hungary, which consists of two vast plains, the one about forty leagues in length and twenty-five in breadth, including that part of Western Hungary which is bounded by the Austrian mountains on the west, the Carpathians on the north, and the Bakony on the south-east; the other about 120 leagues long and eighty broad, forming Lower Hungary, and bounded by the Danube and by the immense marshes which lie on the east of the Theiss at the foot of the mountains of Transylvania. The alluvial character of both these plains, and their low level, which does not exceed 140 or 170 feet above that of the ocean, render it easy to imagine that they have both at a former period been occupied by water, forming two extensive inland seas or lakes, of which that of Balaton, Neusiedel and others are the remains.

The mountain-chain which bounds the most northern of these plains, and separates Hungary from Gallicia, is composed in a great degree of primary mountains, rising in some places to the height of more than 7000 feet. They consist of granite, gneiss, mica-slate, clay-slate and felspathic porphyry, with which are associated certain hornblende rocks regarded

as the *Diabase* of Brongniart, and in one place near Dobschau, serpentine (*gabbro*).

It is on the southern flank of this chain that the volcanic operations have principally taken place, of which such remarkable vestiges remain, although similar phænomena appear to have occurred also near some of the other chains of mountains by which the level portion of this country is bounded. Now as the principal volcanic product in all the above localities is of a trachytic character, there is no other country in Europe where the natural history of that peculiar mineral compound can be so well studied, since from the extended scale on which the rocks classified under this head are here developed in consequence of the large extent of ground which they cover, we are enabled to follow them through all their modifications with a minuteness not practicable either in Auvergne or in Germany, its two other principal European localities.

With a view to acquaint myself more fully with the nature and relations of trachyte, I visited Hungary myself in the year 1823; but as my examination was necessarily limited and superficial, I shall avail myself in a much greater degree of the elaborate work of M. Beudant, in the account I propose to offer of the principal varieties which the trachytic formation of Hungary is found to present.

Beudant enumerates five distinct groups of mountains consisting wholly of trachyte, the characters of which are in all nearly the same, although particular parts of the formation may be more developed in one than in the rest.

The first of these groups, situated in the north-western part of Hungary, namely in the district of Schemnitz and Kremnitz, occupies an elliptical space of about twenty leagues in its greater diameter, and fifteen in its smaller.

The second, a smaller group, south of the preceding one, forms the mountains of Dregeley near Gran on the Danube.

The third is the mountain group known by the name of Matra, situated in the heart of Hungary, east of the former.

The fourth is a chain which commences at Tokai and extends north to the heights of Eperies, in length twenty-five or thirty leagues, and in breadth about five or six.

The fifth, that of Vihorlet, east of the foregoing group, which is connected with the trachytic mountains of Marmorosch on the borders of Transylvania.

Not only do these several groups appear unconnected with each other, but it is Beudant's opinion that almost each particular mountain has been separately formed, for their escarpments rarely correspond, as is the case commonly with those belonging to *plateaux* composed of basalt, so that it is impossible to view them, like the latter, as the detached portions of one general bed cut away by the operation of subsequent causes.

Now in the formation distinguished by Beudant under the generic term of Trachyte, that geologist has noticed five kinds of rock, which, although possessing a common origin, present many important differences one with the other.

These five varieties he has designated under the names of Trachyte properly so called, Trachytic Porphyry, Pearlstone, Millstone Porphyry, and Trachytic Conglomerate.

For the general characters of these I may refer the reader to my second Chapter, but it may be useful to subjoin in this place a more particular account of each as exhibited in the country we are now describing.

Trachyte, properly so called, is characterized by its porphyritic structure, by the scorified and cellular aspect which it has such a tendency to assume, by its harsh feel, and by the presence of crystals of glassy felspar, generally cracked, and sometimes passing into pumice. Besides these, which may be regarded as essential to its composition, crystals of mica and hornblende are often present, and all these minerals are united either confusedly without any apparent *cement*, or by the intervention of a paste of a felspathic nature, sometimes compact and sometimes cellular. This paste is generally light-coloured, though different shades of red and brown are sometimes communicated to it by the presence of iron; and there is one variety in which the paste is perfectly black and semi-vitreous, being intermediate in its characters between pitchstone and basalt, but distinguished from either rock by melting into a white enamel. Augite is sometimes present, and grains of titaniferous iron are often discoverable, but olivine rarely, if ever, occurs, and therefore appears to be the only

mineral which has any claim to be considered as peculiar to basalt.

The second species, called by Beudant Trachytic Porphyry, is distinguished from the preceding by the general absence of scorified substances. Neither hornblende, augite, nor titaniferous iron enters into its composition, but quartz and chalcedony, which are wanting in the former, are commonly present in this species. In its general aspect it bears a much nearer resemblance to the older formations than trachyte properly so called.

This description however applies only to the characters of the larger portion of the mass, for M. Beudant is compelled, in order to include all the varieties, to establish two subspecies, the one *with*, the other *without* quartz, and in both of these he notices a variety possessing a vesicular structure. The subspecies indeed, which is without quartz, even passes into pumice. Many varieties of trachytic porphyry contain a number of very small globules, which seem to consist of melted felspar, having often in their centre a little crystal either of quartz or of mica. The assemblage of these globules, leaving minute cells between them, sometimes gives to the rock a scoriform aspect. The chalcedony often occurs in small geodes, and sometimes intimately mixed with the paste in which the crystals are imbedded.

Trachytic porphyry also appears to pass by imperceptible gradations into the next species, Pearlstone, which is characterized by the vitreous aspect generally belonging to its component parts. It is evident that this definition includes pitchstone and obsidian, but these are of rare occurrence in Hungary, the great mass of this formation being composed of the mineral called pearlstone, some varieties of which pass into pumice.

In its simplest form this rock presents an assemblage of globules, varying from the size of a nut to that of a grain of sand, which have usually a pearly lustre and scaly aspect, and are set, as it were, one upon the other, without any substance intervening.

From this, the most characteristic variety, the rock passes through a number of gradations, in which its peculiarities are more or less distinctly marked. In some varieties the globules are destitute of lustre, and exhibit at the same time

sundry alterations in their size, structure and mode of aggregation, till at length they entirely disappear, and the whole mass puts on a stony appearance which retains none of the characters of pearlstone. On the other hand, the globules, becoming less distinct, either resolve themselves into a paste resembling enamel, very fragile, in which separate portions approaching to a spherical form are indistinctly visible, or into a more vitreous and more homogeneous mass, which is generally black, and presents all the characters of pitchstone or obsidian. Among these latter varieties is one which resembles the *marekanite* of Kamtschatka.

Sometimes there occur in the rock felspathic globules, which are either compact or else striated from the centre to the circumference, and are sometimes so numerous that the whole mass is composed of them. Various alternations occur between the glassy and stony varieties of the pearlstone, sometimes indeed so frequent as to give a veined or ribboned appearance to the rock, and at other times curiously contorted, as though they had been disturbed in the act of cooling.

Lastly, all these varieties occasionally present a cellular, porous, spongy and fibrous aspect, and pass into pumice. With respect to their chemical characters, it may be sufficient to remark that the vitreous varieties of pearlstone usually effervesce under the blowpipe, but the stony do not. These rocks often contain geodes of chalcedony and opal, the former existing in the more vitreous, the latter in the more stony or felspathic portions. The opal is commonly opake, but is occasionally met with more or less translucid.

The fourth species is distinguished for its hardness and cellularity, qualities which have caused it to be employed all over Hungary for the purpose of millstones, from which circumstance the name of Millstone Trachyte has been applied to it by Beudant.

Unlike the other rocks comprised under this same generic term, it abounds in quartz, or in silex under some one of its modifications, and in proportion as the latter earth is more or less abundant, the substance puts on the characters either of hornstone or of clay porphyry. The paste is always dull and coarse-looking, its colours vary from brick-red to greenish-yellow, its fracture is generally earthy, its hardness very variable, but usually considerable. It contains crystals of quartz,

of felspar, lamellar and sometimes glassy, and of black mica, imbedded. Jasper and hornstone also are found in nests, or in small contemporaneous veins, very abundantly disseminated, and siliceous infiltrations, posterior to the formation of the rock, seem likewise to occur among the cells which are everywhere distributed through it.

In examining these rocks with a glass, we discover a multitude of little globules analogous to those in the pearlstone, which seem to be of a felspathic nature, and when broken are found to contain in their centre a little crystal of quartz, or a speck of some siliceous material.

These globules in some cases compose the whole substance of the paste, whilst in others they are held together by a sort of hardened clay, which here and there resembles porcelain-jasper. Notwithstanding these distinctions, there is a greater degree of uniformity in the characters of this than in those of the other species of trachyte, and the most obvious differences that exist between the several parts of this formation relate to the size and direction of the cells, which are sometimes so small and narrow as to give to the rock a fibrous character, sometimes of considerable size, in which case they are in general coated internally with crystals of quartz.

The fifth and last species, comprehended by Beudant under the generic term of Trachyte, consists of those heaps of pumice and other loose materials that occur agglutinated together on the slopes and at the base of rocks belonging to the four preceding classes. Although its prevailing constituent is pumice, every variety of substance found in the neighbouring hills is met with amongst the fragments. The latter vary extremely in size, as well as in the mode of their aggregation; the cement which unites them being often of a porphyritic character, hardly distinguishable from the fragments themselves. Like them it often contains crystals of felspar, mica and hornblende, and sometimes grains of titaniferous iron are diffused through it, or it is coloured red by the peroxide of that metal.

The fragments of pumice are united together either immediately or by the intervention of a paste of a vitreous character resembling obsidian, into which the pumice passes insensibly. Here and there the rock itself has become decomposed, and its destruction has given rise either to beds of a cellular nature

arising from minute portions of pumice, which still preserve their fibrous texture, or (where all traces of this have been obliterated) to masses of an earthy character, similar to the trass of the Rhine volcanos, or the "*tripoli*" of those in Auvergne. It is important to observe, as fixing the date of these conglomerates, that the latter variety contains, between Paloita and Prebeli near Schemnitz, marine shells. These, according to Beudant, are of the same kind as those found in the Calcaire Grossier near Paris, and the bed is covered here and elsewhere by others which he refers to the plastic clay formation.

Boué however has submitted the shells which he collected in that locality to M. Deshayes, and on the authority of the latter they are now placed amongst the Miocene series.

The changes that have taken place in the constitution of this conglomerate seem in some cases to have proceeded a step farther, the earthy beds just noticed as resulting from the reunion of the finely divided portions of the pumice, being rendered compact by the subsequent infiltration of siliceous matter; in this state stems of vegetables of a cylindrical form, often hollow, are found in it in a silicified state, forming those fine specimens of wood-opal so common in this district, whilst crystals of felspar, mica, quartz, and garnet are distributed through the substance of the mass. These latter varieties often bear a considerable resemblance to the millstone trachyte.

The last stage of alteration is seen in the production of a salt composed of sulphuric acid, alumina, and potass, with excess of base, diffused through the substance of the earthy beds before mentioned. According to Beudant, this substance differs from alum in its crystallization, having, so far as the minuteness of the crystals enabled him to judge, a rhombohedral form, and is therefore distinguished by the name of alumstone*.

* There are three minerals often confounded, namely:—

Alum.		*Alumstone.*		*Aluminite.*	
Alumina	10·8	Alumina	31·8	Alumina	29·8
Sulph. acid	33·7	Sulph. acid	27·0	Sulph. acid	23·3
Water	45·4	Water	3·7	Water	46·7
Potass	10·1	Potass	5·8		

It appears likewise from his account, that this salt exists ready-formed in the rock from whence the alum is extracted, and from thence he infers, though as I conceive somewhat precipitately, that the sulphuric acid which enters into its composition has not been derived, as is commonly imagined, from the decomposition of the sulphuret of iron that was originally present. He therefore imagines, that at some former period the rock itself constituted a sort of submarine solfatara, and that owing to a continuance of the volcanic action subsequently to the formation of this deposit, the mass became penetrated with sulphurous acid, which, combining with the alumina, was in process of time converted into the particular mineral called alumstone.

Thus the process in this case will be analogous to that which is taking place at the Solfatara near Naples, and in the craters of other half-extinguished volcanos, and the same remark will apply to the formation of alum at Tolfa in the Roman States, and in other well-known localities.

I have several objections to make to this mode of explanation. In the first place it is by no means universally true, that the subsulphate of alumina exists ready-formed in the alum-rock of Hungary, for in some cases it is only obtained after the mass has become thoroughly decomposed. Though I did not visit the breccia near Matra or Tokai, to which Beudant principally refers in his description, I examined with some attention the works near Vissegrad, between Buda and Schemnitz, carried on by a physician named Marton, who had the kindness to explain to me the details of his process.

In this instance the stone which furnishes the alum is not a tuff or conglomerate, but a trachytic rock containing much pyrites. The object therefore of the manufacturer is to accelerate the decomposition of the latter, and thereby to furnish the acid which enters into the constitution of the alum. This is effected by exposing the stone to air and moisture for a given time, first in the open air, and afterwards in a sort of barn, the roof of which can be raised or lowered at pleasure, so as to exclude the rain, and to admit air and light. The latter agent Dr. Marton considers essential to the success of his process.

The earth is suffered to remain a sufficient time, to effect the decomposition of the sulphuret of iron, the union of the acid which results with the alumina present, and the complete peroxidation of the iron, which is thus rendered insoluble, and no longer affects the purity of the product. Five years generally elapse before the whole is in a state of readiness for lixiviation; it is then reduced to a red ochrey powder, having on its surface an efflorescence of silky crystals,

which probably consist of sulphate of alumina combined with proto-sulphate of iron. However this may be, it is at least certain, that the alkali originally present in the stone is far from sufficient to convert the whole into crystallizable alum. Having therefore separated the saline matter by lixiviation, Dr. Marton finds it necessary to add about five per cent. of subcarbonate of potass, after which the solution being boiled to a state of sufficient concentration, is set aside to crystallize.

This statement may be sufficient to show, that Beudant's position as to the alum existing ready-formed in the rock, does not hold good universally; but even where this is the case, it by no means follows, that the salt may not have originally proceeded from the decomposition of the sulphuret of iron. Let us recollect, that the alum-rock of Matra is a bed, resulting in part at least from the detritus of the trachyte which we have seen to be so fully charged with iron pyrites, and so capable of yielding alum in consequence, and that the very cause which has brought its materials into their present position, would be the one most efficient in occasioning the decomposition of a metallic sulphuret. Even if it were impossible to account for the formation of the alumstone in this manner, I should still hesitate as to adopting M. Beudant's explanation, because the rock is not stated to possess any of the characters belonging to the substances found near a modern solfatara, and does not appear to be impregnated either with sulphur, or with the other minerals produced, when either sulphuretted hydrogen or sulphurous acid has pervaded a mineral mass for the period which must be necessarily supposed.

The trachytic formation is in general devoid of those metallic veins which so commonly penetrate the older porphyries in Hungary, but at Konigsburg near Schemnitz, the conglomerate belonging to it is richly impregnated with auriferous sulphuret of silver, which pervades the mass, and is separated by simple washing. The gold-mines of Telkebanya, near Tokai, appear to be situated in the same description of rock, so that it is by no means correct to say that the absence or presence of depôts of these metals serves to distinguish the newer from the older porphyry, although it may perhaps be true, that it is only in the latter that true veins are to be met with.

Amongst the siliceous minerals so common in the trachyte of Hungary, the different varieties of opal have principally attracted attention. They are met with for the most part in the trachytic conglomerate, but they occur also in the pearlstone.

Hyalite I have myself seen, in more than one instance, coating the fissures of the trachyte, derived perhaps from a sublimation of the silica by the volcanic action, or from a chemical solution of that earth by steam proceeding from the same source. The same remark has been made by Von Buch with respect to the island of Lancerote.

According to Beudant, the five species of rock included under the generic name of Trachyte, always preserve with relation to each other the same determinate order; that properly called trachyte occupying the central portion of the group; the trachytic conglomerate surrounding the flanks of the mountains; whilst the trachytic porphyry, the pearlstones, and the millstone porphyry lie intermediate. There is however no appearance of stratification, or of any pause having taken place in the volcanic operations, so that we cannot suppose the most ancient part of the formation to have been produced at a different epoch from the most modern, and are therefore under the necessity of regarding the observations that have been made with respect to the rocks which cover the trachytic conglomerate, as determining equally the date of the whole.

With regard to the origin of this trachytic conglomerate, it is the opinion of Beudant, that as the fragments contained in it sometimes appear to be rolled, a part of its materials was derived from the debris of the surrounding country; but that, as the latter supposition cannot be applied either to the case of the pumice which constitutes the larger proportion of this deposit, or to that of the angular fragments of other substances which also occur in the midst of it, the greater part of its constituents have probably been ejected immediately by the volcanic action.

The following is a synopsis of the genus Trachyte, as given by Beudant, which should be compared with the classification of the same rock proposed by more modern writers.

1st Species, TRACHYTE, properly so called.

1st variety, *granitoid*—no apparent cement, numerous crystals of glassy felspar confusedly united; crystals of black mica; hornblende rare.

2nd, *with mica and hornblende*—these crystals abundant and generally black; paste of compact felspar, pretty pure, and fusible into a white enamel; crystals of glassy felspar.

3rd, *porphyritic*—paste of compact felspar, fusible into a white enamel; crystals of felspar, glassy, lamellar, and compact; augite more or less abundant; no mica or hornblende.

4th, *black*—the paste black, dull, fusible into a white enamel, with black spots, more or less numerous, disseminated; crystals of glassy felspar, sometimes of augite.

5th, *ferruginous*—paste ferruginous, dull, of a red or brownish colour, blackening when heated; fusible into a black or scoriform enamel; crystals of glassy felspar; numerous crystals of black mica.

6th, *earthy or domite*—paste earthy, porous, light-coloured; crystals of glassy felspar rare; crystals of black mica abundant.

7th, *semi-vitreous* (*Pseudo-basalt of Humboldt*)—paste semi-vitreous, black or brown; fracture large-conchoidal, losing its colour in the fire, and melting into a white enamel.

8th, *cellular*—paste of various descriptions; contains numerous cells more or less imperfect, either round or elongated.

2nd Species, Trachytic Porphyry.

1st Subspecies, *with crystals of quartz*—base of compact felspar, with or without lustre, more or less abundant, containing most commonly a great number of small semi-vitreous globules; crystals of quartz more or less numerous; crystals of glassy felspar, generally well-defined; black mica, in small hexagonal plates, more or less numerous.

1st variety, *glistening*—base composed of compact felspar with an enamelled surface, easily fusible.

2nd, *semi-vitreous*(vitro-lithoide)—almost entirely composed of semi-vitreous globules, amongst which are disseminated crystals of glassy felspar, and some of quartz.

3rd, *scoriform*—paste semi-vitreous and dull, porous, or with irregular and imperfect cells.

4th, *cavernous*—paste scarcely discernible; small and very numerous cells; irregular cavities of various sizes; mass infusible.

2nd Subspecies, *without quartz*—base of compact felspar with or without lustre, more or less fusible before the blowpipe; small crystals more or less numerous, often with imperfect terminations, of glassy or earthy felspar; black mica in small hexagonal plates; no crystals of quartz or semi-vitreous globules.

1st variety, *glistening*—base of compact felspar, easily fusible into a white enamel; small crystals of felspar, commonly of the glassy kind.

2nd, *dull*—base of compact felspar, dull, difficultly fusible before the blowpipe; small crystals of felspar, commonly earthy, sometimes very rare.

3rd, *cellular or pumiceous*—base almost infusible; full of cells; crystals of felspar rare and indistinct.

3rd Species, Pearlstone.

1st variety, *testaceous*, made up of an assemblage of vitreous globules more or less distinct, generally scaly (*testacés*) and with a pearly lustre; mica and felspar very rare.

2nd, *spherolitic*—paste of pearlstone not testaceous, with an enamelled lustre and a grey colour; numerous crystals of very brilliant black mica; glassy felspar in small crystals, ordinarily with their terminations imperfect.

3rd, *pitchstone*—vitreous paste approaching to obsidian, often with a fatty lustre; crystals of glassy felspar with imperfect terminations; little geodes of chalcedony more or less numerous.

4th, *globular stony*—stony mass, composed of globules with a compact or radiated structure, semi-vitreous or altogether stony.

5th, *stony in mass*—the whole mass semi-vitreous, or altogether stony; the structure passing sometimes into porphyritic.

4th Species, Millstone Porphyry.

This species is so uniform in its composition, as not to admit of being distinguished in the manner of the preceding.

5th Species, Trachytic Conglomerate.

1st, *the conglomerates made up of the debris of trachyte*, cemented by an earthy or more or less crystalline paste.

2nd, *the conglomerates consisting chiefly of the trachyte and millstone porphyry*—rounded or angular.

3rd, *the conglomerates pumiceous*, composed of fragments of pumice and obsidian, agglutinated either immediately, or by the intervention of some cement more or less earthy.

4th, *the conglomerates porphyritic*, caused in the first instance by the decomposition of the pumice, but containing crystals which have resulted from a subsequent play of affinities within the mass.

5th, *the aluminous beds*, consisting of tufaceous or conglomerated rocks impregnated with alum.

I have now, by the assistance of Beudant's laborious and apparently accurate treatise, presented an account of the trachytic formation as it exists in the country where it is most fully developed, and have been induced to enter more into particulars than it is my purpose in general to do, as I am not aware of any so detailed account of this class of rocks existing in the English language; a deficiency arising probably from the total absence of the formation itself from all parts of the British dominions.

Not but there are some rocks even among ourselves which remind us of the trachytes of Hungary, although not absolutely referable to the same class. The clay porphyry associated with red sandstone in the Isle of Arran, and that of Sandy Brae in the county of Antrim, present at least numerous analogies with them, and the latter rock not only passes into pitchstone, sometimes resembling the pearlstone of Hungary, but also contains nests and veins of wax opal.

The two formations are indeed distinguished by the constant absence of scorified matter from the porphyries of Ireland and of Arran, and its occasional presence in those of Hungary, but this difference will I hope be satisfactorily explained hereafter, by considering their several ages, and the manner in which the agency of heat upon them has been modified by this circumstance. The porphyry of Arran is interstratified with red sandstone, and that of Sandy Brae, though an overlying mass, is probably referable to the same æra as the basalt of the Giant's Causeway, which seems to be about the date of the chalk; whereas the trachyte of Hungary would appear, from its containing shells belonging to the Paris basin, not to be older than the miocene period.

Though therefore all these rocks may have been produced under water, yet we may readily suppose the pressure exerted by the ocean to have been greater in the one case than in the other, and may thus explain the absence of scorified matter, without supposing the Arran and Irish porphyries to have been produced by causes essentially different.

But we need not look further than Hungary itself for a class of rocks presenting an equal analogy with trachyte, but accompanied with differences similar to those just pointed out.

I have already enumerated amongst the primary rocks of this country a porphyry consisting essentially of compact felspar and of hornblende, which appears to alternate with syenite, with mica slate, and even with granite.

The frequent resemblance which this rock bears in mineralogical characters to trachyte, from which however the absence of cellularity and of vitreous structure clearly distinguishes it, proved a subject of great perplexity to me at the

time I visited Hungary, when the fact of granite being of comparatively recent eruption was as yet but partially acknowledged.

Granting the porphyry to have been contemporaneous with the granite, and the granite to be of more ancient date than the whole range of transition, secondary, and tertiary rocks which had preceded the eruption of the trachyte, it appeared singular that if the former no less than the latter were of igneous formation, the same agent should have occasioned similar effects at epochs so incalculably remote, without leaving any vestiges of its operation as the product of an intermediate period.

Or if the igneous origin of granite was denied, and that of porphyry was in consequence disputed, how were we to explain the production of a rock so analogous to trachyte by the operation of causes altogether different from those which had given birth to the latter?

But upon reviewing the subject with the lights which modern investigations have afforded, I find nothing certain with regard to the age of the porphyry or of its associated rocks. It seems possible, so far as we at present know, that even the granite may have been ejected at a period comparatively modern, and we are therefore at liberty to regard the whole of the igneous formations of Hungary as belonging to the same geological epoch, and to have been modified only by certain differences in the conditions under which they were severally ejected.

The compact nature of the one, the occasional cellularity and vitreous state of the other, clearly indicate the absence or presence of pressure whilst the rocks were undergoing the process of cooling,—a difference, the causes of which will be a subject of after-consideration. We shall find that the same association of trachyte with greenstone porphyry occurs in Mexico, and that the latter rock in both these localities abounds in mines of gold and silver.

The pretended passage of greenstone porphyry into trachyte does not appear to be substantiated, for although the former rock when in contact with the latter may put on in some degree the same characters, yet this circumstance may probably be accounted for by the action of the heated mass of

trachyte upon the surface with which it was in immediate contact.

The trachytic formation is sometimes accompanied by detached cones of basalt, as at the Calvarienburg, near Schemnitz; but the principal masses of that rock lie at a considerable distance near the lake of Balaton, where they occur in the midst of a sandy plain, either in detached cones or in elevated tabular masses.

Not having visited that part of Hungary, I am unable to state whether or not they are posterior to the formation of the valleys; but the quantity of highly porous and scoriform substances with which they are said to be associated seems to indicate a recent origin. It is certain at least from Beudant's account, that they could not have been anterior to the tertiary class of rocks: since he observed them, they are seen in several places resting upon molasse.

CHAPTER VI.

VOLCANIC ROCKS OF TRANSYLVANIA.

Direction and extent of the chain.—Trachytic conglomerates and trachytic cones.—Craters near Tuschnad.—Sulphureous vapours at Budoshegy.—Hot springs at Borsah.—Pumice ejected.—Cone of trachyte in Schlavonia.—Cellular basalt near Güns.

In Transylvania*, volcanic rocks of undoubted tertiary origin occur in the eastern part of the country alone.

The above formation constitutes a range of hills covered with thick wood, which separates from Transylvania the Szeckler land, or the valley in which the Hungarian tribe of that name reside.

The chain itself extends from the high hills of Kelemany, north of Remeszel, to the hill of Budoshegy, about ten or twelve miles north of Vasarhely. The wild tract included within this mountainous range is so broad, that it requires a day's journey to cross it in a carriage; at its northern extremity, however, it gets gradually narrower. Its limits are,

* I am indebted for the whole of this account of Transylvania to Dr. Boué, the author of a Geognostical Essay on Scotland, of several interesting papers on the Geology of France and Germany, and of an elaborate work on European Turkey which will be afterwards referred to. The value of the sketch here given is enhanced from the circumstance, that no individual, so far as I am aware, has communicated to the public any description of this remote country since the branch of natural history which relates to the physical structure of the earth had begun to assume its present form. Dr. Boué's design comprehended the whole of the Bannat, and the provinces of the Austrian empire as far as Trieste; but a severe illness, occasioned by the villainy of a servant, who attempted to poison him, in order the more readily to make off with his money and property, brought his researches at that time to an abrupt termination. Before however this event occurred, he had examined a great part of the southern and eastern portion of Hungary, including the trachytic formation of Transylvania, and published a report of what he had seen in the first volume of the Memoirs of the Geological Society of France, of which the annexed account is an abstract. See also in the same volume, a Memoir by Boué, founded on the Notes of the late M. Lill de Lilienbach.

to the east the river Marosch from Toplitza upwards, the Aluta from Varosch to Tuschnad and Kasson; to the west, a line passing through Kasson, Tulle, Udyarhely, Parayd, Libonfalva and Pata. It is for the most part composed of various kinds of trachytic conglomerate, of which the best sections are presented along the course of the Marosch, for elsewhere a most impracticable forest of pines and oaks covers it nearly throughout. From the midst of these vast tufaceous deposits, the tops of the hills composed of trachyte, a rock which forms all the loftiest eminences, here and there emerge. Of these the most elevated is called Kelemany; the other principal ones are Fatatschion, Pritzilasso, Hargala, Barot, the hills south of Tuschnad, &c. &c. The trachyte is ordinarily reddish, greyish, or blackish; it mostly contains mica. In the southern parts, as near Tschik Sereda, the trachyte incloses large masses, sometimes forming even small hillocks, of that variety of which millstones are made, having quartz crystals disseminated through it, and in general indurated by siliceous matter in so fine a state of division that the parts are nearly invisible. The latter substance seems to be the result of a kind of sublimation, which took place at the moment of the formation of the trachyte.

Basalts were nowhere observed, although black trachyte abounds. Distinct craters are only seen at the southern extremity of the chain. One of the finest observed by Dr. Boué was to the south of Tuschnad; it was of great size and well-characterized, surrounded by pretty steep and lofty hills composed of trachyte. The bottom of the hollow was full of water. The ground near has a very strong sulphureous odour. A mile in a S.S.E. direction from this point there are on the table-land two large and distinct "maars," like those of the Eifel, that is to say, old craters, which have been lakes, and are now covered with a thick coat of marsh plants; the cattle dare not graze upon them for fear of sinking in.

Some miles farther in the same direction is the well-known hill of Budoshegy (or hill of bad smell), a trachytic mountain, near the summit of which is a distinct rent, exhaling very hot sulphureous vapours. The heat of the ground is such as to burn the shoes. A deposition of sulphur has taken place there, and the rock is converted into alum-stone by the

action of the vapours upon the constituents of the trachyte. In this manner hollows are formed in the rock. At the base of the hill are some very fine ferruginous sulphur springs, much resorted to for various diseases by the inhabitants, who encamp near them in the open air during summer. Chalybeate sulphur springs generally abound at the base of this volcanic range, and chalybeates with carbonic acid still more. Some of these appeared as good as those of Pyrmont, and the most famous, that of Borsah, a bathing-place much resorted to by the Transylvanian nobles, contains more carbonic acid than Pyrmont water itself.

The craters last described have thrown out a vast quantity of pumice, which now forms a deposit of greater or less thickness along the Aluta and the Marosch from Tuschnad to Toplitza. Impressions of plants and some siliceous wood are likewise to be found in it, as is the case in Hungary. These fragments of pumice have been deposited under water. Some, says Dr. Boué, might be disposed to set down a more considerable portion of Transylvania as trachytic than I have done, but I have satisfied myself that many rocks which may appear to be trachyte are nothing but some of the newer transition or coal-sandstone porphyries, which are here and there more scorified than elsewhere, or of which the scorified portions have stood the action of the weather better than the rest. This may be the case with the most recent porphyries of the two great deposits of that formation, the one of Marmorosch, the other in the Gespannschaft (comitat) of Hunyad and the Stuhl of Muhlenbach.

To this account of the volcanic rocks of Transylvania I have only to add that a basaltic cone is mentioned by Beudant as occurring in Schlavonia near Peterwaradin, and that I myself saw in the possession of Professor Schuster at Buda, specimens from that province, and probably from the same locality, which from their scoriform aspect I should judge to be of modern formation.

Dr. Boué also informs me that between Ober-Pullendorf and Stoop, near Güns in Hungary, south of the lake of Neusiedel, is a flat conical hill about 100 feet in height, half a league in its greatest diameter, and a quarter of a league in

its smallest, which rises from the midst of the upper tertiary deposits, or amongst the marly beds lying above the blue shelly marl common to Austria and the Apennines. The rock itself is composed of a blackish or greyish felspathic basalt, which is sometimes compact, and contains oval nodules, partly of mamillary or botryoidal iron ore, and partly of arragonite; sometimes very porous, and with the cavities either entirely empty, or coated with globules of sphærosiderite.

The direction of the cells is from E.N.E. to W.S.W., and the same is the direction of the range itself. It is decidedly a tertiary basaltic cone, having its base only covered by recent marls.

CHAPTER VII.

VOLCANIC ROCKS OF STYRIA.

Volcanos of Styria.—Trachyte of Gleichenberg near Grätz.—Age of the beds surrounding it.—Mode of accounting for the position occupied by the trachyte.—Trachyte of Cilli.

On my way from Vienna into Italy in 1823, I deviated a little from the direct road, in order to look at some rocks of a volcanic nature that occur near Friedau in Styria, a little to the south-east of Grätz, of which the only account that had been published was a short one by Von Buch, in the Transactions of the Academy of Berlin.

The formation in question may be briefly stated as consisting of a central nucleus of trachyte, which constitutes the lofty conical hill called the Gleichenberg, round which on all sides apparently are mantle-shaped strata of volcanic tuff, alternating with beds belonging to the tertiary class.

The tuff consists in general of a congeries of very minute fragments of volcanic matter, which seem to have been immediately ejected from the volcano, mixed up and loosely agglutinated with small quartzy pebbles. In the midst of it are fragments of cellular and compact basaltic lava, sometimes containing *nests* of olivine. Masses of the same substance of a globular form, not imbedded in any matrix, are found also distributed amongst the tuff. Specimens of augite, and of a substance looking like altered granite, likewise occur. The tuff, becoming more and more mixed with particles of clay and sand, passes at length into a loamy earth, at first dark, and afterwards, where it is unmixed with volcanic matter, of an ash-grey colour. The constituents are in a state of very fine division, and a number of minute specks of silvery mica impart a sparkling lustre to the general mass, and give it the appearance of a bed of silt deposited tranquilly at the bottom of a lake.

At a village called Khelig, a little to the south of the former

locality, I observed that the tuff, which here contained decided scoriæ, was superimposed on a rock which nowise differed from ordinary basalt, except in the existence of minute internal pores. It formed a number of concentric lamellar concretions, of which the external have become decomposed, whilst the internal retain their solidity. The exterior surface of the balls is coated with asphaltum. The whole rests upon a bed of marl without any traces of volcanic matter.

We find, at a somewhat greater distance from the central trachyte, strata of limestone full of shells, belonging to the most recent order of deposits, amongst which the miliolite occurs, but which consists in a great degree of a conglomeration of little oval concretions, which give to the rock exactly the appearance of the oolite of our own country.

Professor Sedgwick and Sir Roderick Murchison, who in the year 1829 visited this district, consider the above-mentioned rocks as belonging to the newest of the three groups into which they divide the tertiary formations of Styria and Austria.

But Mr. Lyell sees no sufficient reason for separating the beds which belong to this newest division from those of the miocene period, and consequently regards the principal eruptions of volcanic matter which took place in that province as having begun at the same epoch.

Respecting the age at which the igneous causes ceased, these authors offer no conjecture. We do not find traces of their action since the sea retired from the bays of Lower Styria, as no igneous rocks follow the direction of the valleys or inclined planes presented by the existing surface of the country. On the contrary, they rise in steep insulated masses, formed, evidently, before the rivers drained through their present channels; and they offer most emphatic proofs of the enormous degradation and waste of the country since the formation of one of the newest regular deposits known in geology.

Two hypotheses present themselves with respect to the age of the trachyte of the Gleichenberg; for it may either be said, that having been first thrown up by volcanic action, the beds of tuff and of marl collected by degrees around its base; or that after the latter had been formed in a position approach-

ing to the horizontal, the rock of the Gleichenberg, being forced up through the midst of them, imparted the inclination which they are now seen to possess.

For my own part I am most disposed to adopt the latter opinion, on the same ground on which I assented to M. Bertrand Roux's ideas with respect to the rock of the Mont Mezen; for it seems probable that if the trachyte had been formed in the first instance, fragments of it ought to appear intermixed with the other materials of the tuff, which I did not discover to be the case. The inclination likewise possessed by the strata of tuff seems to me too considerable to be consistent with the former hypothesis, but accords very well with the latter.

The following sketch may give an idea of the disposition of the central trachyte.

Where *a* and *b* are alternating beds of tuff and loam or sand, C is the trachyte, and D a valley of denudation separating the two rocks.

Messrs. Sedgwick and Murchison did not examine this volcanic region, but they remark, that in the hill of Feresh, the alternating beds of tertiary sand and volcanic tufa are nearly horizontal. This however did not appear to be the case as to those I observed in the immediate neighbourhood of the Gleichenberg.

Further to the south, near the town of Cilli on the southern side of the river Savi, Professor Studer in the year 1827 discovered rocks consisting of trachyte; but I am unable at present to refer to any detailed account of their character or relations.

CHAPTER VIII.

VOLCANIC ROCKS OF NORTHERN ITALY.

Volcanos of Northern Italy.—Euganean hills.—Trachyte—associated with Scaglia.—Vicentin, cellular and compact volcanic rocks.—Monte Bolca. —Bassano.—Formation of the tuff.—Volcanic rocks near Lake Lugano, and Lake Como.

The volcanic rocks of Italy may for convenience sake be considered under three several heads, namely—1st, those occurring north of the Po, or in Lombardy; 2ndly, those extending from the north of Tuscany, through the Roman territory, to the Pontine Marshes; and 3rdly, those found in various parts of the kingdom of Naples. The first may be designated the volcanos of Northern, the second of Central, and the third of Southern Italy.

Although volcanic operations appear at present to be proceeding only in the last-mentioned locality, and therefore give to it in point of interest a prominence over the other parts of the Peninsula in relation to our present subject, it will nevertheless be best to consider the whole in geographical order, beginning with the Venetian territory as the most northern.

On entering Italy by the side of Venice, we have not far to go before we meet with a very extensive and interesting volcanic district.

To the south of Padua lie the Euganean hills, an isolated tract of high ground in the midst of a level country, consisting of a trachytic formation, not unlike that of Hungary, which from its cellular structure in some cases, and its semi-vitreous aspect in others, would at once be taken for a volcanic product. Like that formation too as developed in the latter country, it consists of several kinds of rock, which however are so allied, and so connected by mutual passages, as to show that they have been all derived from a modification of the same process.

The most characteristic variety is a rock of an ash-grey colour and uneven fracture, very like the porphyry of Mont Dor, or the first species of Beudant's trachytic formation (Monselice). It contains numerous crystals of glassy felspar, sometimes decomposed, sometimes fresh, and occasionally specks of black mica, which is also accumulated in *nests*, the several parts of which have a slaty structure, like that of mica slate. Crystals of augite are also found under the same circumstances. Associated with this is a rock possessing a splintery fracture, waxy lustre, and vitreous appearance, which may be called a hornstone porphyry. Some varieties are cellular, and contain infiltrations of quartz and chalcedony, like the millstone trachyte of Hungary; others approach very nearly to the characters of pearlstone, presenting, together with the vitreous aspect of that substance, an approach to a similar concentric arrangement (Monte Siave). In these cases the crystals of glassy felspar, which distinguish true trachyte, are either absent, or very rarely occur.

This formation is associated at Monte Venda with basalt, the relation of which to the trachyte is as obscure as it is in the parallel case of the Siebengebirge. It is also surrounded, at Castelletto, by strata of tuff and of pumiceous conglomerate, in a manner analogous to what I have described as taking place near the Gleichenberg in Styria, but disposed more vertically.

In some parts a conglomerate or breccia occurs (Monte Nuovo), which seems to be principally made up of the hornstone above described, intermixed with a white powdery siliceous substance which fills up the interstices. The whole of this mass might be imagined, as well from its vitreous appearance as from the intimate union of its parts, to have been consolidated by fusion, or at least by the action of heat.

The trachyte of the Euganean hills rests upon a calcareous rock, which appears to correspond with the chalk of Great Britain. It is called Scaglia, from its slaty structure, being disposed in thin horizontal layers. Its colour is commonly white, now and then with a shade of red, and its compactness usually is quite equal to that of our hardest chalk, though softer varieties are sometimes met with.

The points however chiefly to be insisted on, as establish-

ing the identity of the two formations, are, the kidney-shaped masses of flint disposed in beds throughout the scaglia, as in the chalk of England, and the nature of the petrifactions that occur in it, which, from the list given in the Abbé Maraschini's work *, appear to consist of Ammonites, Terebratulites, and various species of the Echinus family; viz. the Echinoneus, Galerites, Ananchytes, Spatangus, Cidaris, Nucleolites, and Echinus *proper*, of Lamarck.

By comparing this list with the one given in Messrs. Conybeare and Phillips's 'Geology of England and Wales,' p. 73, it will be seen that the analogy between the two formations is in this respect considerable.

Pollini however maintains, that there is in fact no broad line of distinction between the scaglia and the tertiary beds, for the calcaire grossier of Verona passes into and even alternates with the scaglia, which again graduates into an oolitic limestone with fossils belonging to the oolitic series. Nummulites too occur not only in the tertiary rocks, but also in the scaglia, and even as low down as the Jura limestone.

This conclusion is adopted by Sir Roderick Murchison, who remarks, that near Bassano we find a continuity of marine deposits from the latest tertiary to the secondary series of formations.

He however entirely coincides in the conclusion which I had adopted in the first edition of this work, as to the identity of the scaglia with the chalk of England.

I know not whether the redness and brittleness of the flints in a part of the rock which lies near the trachyte, not far from the village of Battaglia, is to be explained in the same manner in which Messrs. Buckland and Conybeare have accounted for a similar change in some of those near the Giant's Causeway, namely, by the influence of the melted matter upon them; but it is at least certain, that this volcanic rock has sometimes produced, upon the surface of the subjacent bed, alterations, which afford additional evidence of its igneous origin.

Thus at the village of Schevanoya, on the southern slope of the Euganean hills, the trachyte is incumbent on an argil-

* Sulle Formazioni delle Rocce del Vicentino (Padova, 1824), p. 122.

laceous variety of what I presume to be scaglia, which is naturally so incoherent as to be softened by every shower of rain. As we trace it upwards however, we find it gradually becoming more and more compact, until at last, where it touches the incumbent trachyte, it becomes perfectly hard and splintery in its fracture.

But the trachyte of this, and I may add, of other allied localities in the north of Italy, is posterior not only to the chalk, but also, as it would appear, to some of the tertiary formations incumbent. Professor Savi has observed, that the trachytes of Tuscany, which will be noticed presently, traverse in the vicinity of Volterra and of Grosseto the subapennine beds; and the Marchese Pareto has satisfied himself of the same fact at Monte Cimini. Count da Rio and Signor Pasini too have seen the trachyte of the Euganean hills traversing tertiary rocks, and that of the Ponza Islands appears to do the same.

All these trachytic formations therefore may be inferred to belong to the same epoch, and that a very recent one.

Other indications of volcanic action may perhaps be gathered from the springs of hot water impregnated with sulphuretted hydrogen, which gush out from the rock near the village of Battaglia*, and are still in repute, as they were in the time of the Romans, for their medicinal qualities.

Perhaps the fable of Phaëton †, who was said to have fallen from heaven, or to have been struck by lightning on the

* It was the Fons Aponi mentioned by Lucan, lib. 7:

Euganeo, si vera fides memorantibus, augur
Colle sedens, *Aponus terris ubi fumifer exit,*
Venit summa dies, geritur res maxima, dixit;
Impia concurrunt Pompeii et Cæsaris arma.

Claudian also celebrates it.

† Tzetzes, in his Schol. on Lycophron, says, that some supposed the Lake Avernus to exist among the Euganean hills, and the circumstances that gave rise to the fable of Phaëton to have happened there. Martial too has these lines:

Æmula Baianis Altini littora villis,
Et Phaëthontei conscia sylva rogi;
Quæque Antenorio, Dryadum pulcherrima, Fauno
Nupsit, ad Euganeos sola puella lacus!

borders of the Po, may refer to some tradition that existed of volcanic phænomena, which might have continued here long after the formation of the trachyte, as they now do in Transylvania, an idea which I perceive had also struck Sir Humphry Davy *.

The neighbouring country to the north of Vicenza is interesting to the volcanist, as enabling him to trace the differences that exist between the ignigenous rocks of the very same country, according to their relative degrees of antiquity.

It appears that all the formations of that country from the talc slate, which is the fundamental rock, up to the scaglia †, which is an equivalent of our chalk, are accompanied by trap rocks, both in beds and in dykes, having a uniformly compact structure, or cells completely filled with crystalline matter; whereas the tertiary beds that lie above them all alternate with a tuff, consisting of materials, the volcanic nature of which is more plainly attested by the scoriform and vitreous aspect which so often belongs to them. It is impossible to imagine any combination of phænomena more in accordance with the idea, that the compactness of lavas is regulated *cæt. par.* by the pressure which they have undergone, and that the absence of vacuities in the case of all those formed during the deposition of the older rocks, arose from the fluid mass superimposed; since it is seen that the products of volcanos in action subsequently to the date of the chalk, produced probably in comparatively shallow lakes, rather than in deep water, approximate in their characters more nearly to the

* See his posthumous work entitled 'Last Words of a Philosopher.'

† The Abbé Maraschini was good enough to show me a hill, near Recuaro, north of Schio, where according to him the greater part of the formations met with in that neighbourhood are seen united. In his Memoir entitled "Observ. soprà alcun. Local. del Vicent.," which was published in the 'Biblioteca Italiana,' and in his late work referred to above, a full enumeration of the series is given; I shall therefore content myself with stating, that on this hill are seen, resting on the talc slate, which appears to be the fundamental rock of the country, 1st, a red sandstone, 2nd, an augite rock (dolerite), 3rd, another red sandstone with seams of slate-coal, and above, three alternations of sandstone and limestone, which the Abbé is inclined to refer, I know not how correctly, to distinct formations analogous to those in England and Germany.

ignigenous formations of the present day*. It has even been remarked, that a difference appears to subsist between the volcanic rocks in the Vicentin of anterior date to the scaglia, corresponding to their respective ages†; the dykes which penetrate the older formations producing a greater hardening, and in general a more marked alteration in the part contiguous to it, than those which traverse the more modern. I do not however believe that this remark can be generalized, for the effects of dykes on the adjoining surfaces of the rocks they traverse are nowhere more marked than at the Giant's Causeway, where they are at least as modern as the chalk.

I shall therefore omit all mention of the older formations of the same description found in this country, and content myself with comparing together the trap rocks associated with the scaglia, and the volcanic tuff which accompanies the tertiary beds that rest upon it.

Near Schio, north of Vicenza, the scaglia occupies the lowest part of the valley of Cengiette, and rises to a considerable distance on the hills of either side. At the hill of Belmonte, a rivulet exposes five stratiform masses of basalt, often changed by decomposition into wacke, which I am disposed to consider, with Dr. Boué, as dykes parallel to the stratification of the chalk. Dykes of basalt are also frequently seen traversing this formation, at Chiampo, Valdagno, and Magre, but not altering the adjacent rock; the external portion of the dyke is frequently so much decomposed as to be converted into a sort of clay.

Above this is a thick and extensive formation of greenstone porphyry, or porphyritic augite rock, which the Abbé Maraschini sets down as corresponding with the trachyte of the Euganean hills. It lies in a sort of basin, filling up all the pre-existing hollows between the older rocks. Thus in some places it rests immediately on chalk, and in others on rocks of an older date.

This porphyry has generally a claystone base with crystals of augite disseminated. It is of various shades of brown, with reddish or greyish spots, sometimes more or less vitreous

* See Maraschini in the work above quoted, p. 130.

† Maraschini.

in its fracture, passing even into pitchstone or obsidian porphyry. It is generally very tough, but where it has undergone decomposition, has passed into the state of kaolin.

The most remarkable circumstance attending it is its containing veins of metallic matter, for we do not usually find the latter accompanying rocks of a volcanic nature, or of a date so recent as that which must be assigned to a formation covering the scaglia. Near Schio, where its superposition is distinctly seen, the porphyry is penetrated by veins of blende, galena, arsenical pyrites, sulphate, carbonate, molybdate, and (according to Professor Catullo) chromate of lead, accompanied with quartz crystals, calcareous spar, sulphate of barytes, and manganesian epidote *. The upper part of this formation becomes amygdaloidal, containing cells which are for the most part filled with calcareous spar, chalcedony, and various species of zeolites. The preceding rocks are covered with numerous alternations of calcareous with brecciated or tufaceous deposits.

The former are regarded as tertiary, from the occurrence of nummulites and other shells enumerated by Brongniart in his Memoir on the Vicentin †; the latter are made up of fragments not only of basalt, but also of volcanic sand and scoriform lava, thus indicating the commencement of a new order of volcanic products. The tuff is often as fully charged with shells as the limestone rock itself, abounding in nummulites, &c. &c.; it also contains large masses of brown coal, and even of silicified wood. In the midst of the calcareous beds above mentioned, are some consisting of a bituminous slaty marl containing impressions of fish; they occur at Monte Bolca, at Monte Novale near Valdagno, and at Monte de Salzedo.

At Monte Bolca, the only locality which I visited, the Ichthyolite limestone, as it may be called, rests upon a calcareous rock with nummulites, and is covered by the same; whilst a deposit consisting of volcanic tuff lies both under and above it. The alternations indeed between these two classes of deposits are often extremely numerous; at a place called Ronca alone we have in a very short compass no less

* Maraschini, p. 133 *et seq.*

† Brongniart sur les Terrains calcareo-trappeens du Vicentin. Paris, 1823.

than six, but the lowest volcanic bed is not tufaceous, consisting of cellular basalt. The occurrence of this substance, sometimes cellular, sometimes amygdaloidal, and sometimes even compact, interstratified with the other rocks, renders the structure of the Vicentin less simple than it would otherwise be considered, and inclines one to think that streams of lava were thrown out during the formation of the tufaceous and calcareous beds.

The perfect condition in which the impressions of fish are found in the rock of Monte Bolca, their extraordinary abundance, and the appearance which some of them present of having perished in the very act of devouring their prey, seem to show that the catastrophe which destroyed them was a sudden one, such as might have been brought about by the evolution of some of the noxious gases exhaled from volcanos. I have myself observed the speedy extinction of life which takes place, when carbonic acid is introduced into a vessel in which river fish of several different kinds are collected, the first operation of the gas causing them to leap out of the water with convulsive energy, but in a few seconds all muscular movement being suspended, and the fish without any further effort sinking lifeless to the bottom of the tub.

That the whole indeed of the basaltic, as well as the materials of the tufaceous rocks are referable to igneous action, no one can for a moment doubt, although Brocchi, the first of Italian geologists, expressed himself in his Memoir on the Val de Fassa with some degree of hesitation on the subject*.

Admitting even that there are whole beds of tuff which exhibit no traces of igneous action, yet these are so associated with others containing volcanic products of the most unequivocal kind, that I know not how we are to separate the one from the other.

Even the compact basalt passes, at Monte Glosso near Bassano, into a vitreous rock, which approximates to obsidian; nay, we discover in the tuff itself at Chiampo, large detached masses of cellular lava, the cavities of which have often that glazed surface which so strongly indicates fusion.

At the same time, the presence of shells in the tuff itself,

* This memoir was published many years ago, so that it may not represent his later views.

and its alternation with regular beds of unaltered shelly limestone, prove that the sandy matter and loose fragments of which this aggregate is composed were originally deposited under the surface of water, at the period during which the calcareous beds were in the act of forming. That the accumulation of the materials of which the tuff consists was a slow and gradual process, I infer, among other reasons, from a specimen in my possession, in which a rounded fragment taken from one of these beds is seen covered by serpulæ, a plain proof that the stone remained for some time under water, uncovered by any of the matter which afterwards formed above it.

The occurrence therefore of beds of volcanic tuff alternating with strata of shelly limestone, seems in this instance capable of explanation, by supposing showers of ashes and lapilli to have proceeded from some adjacent volcano, which, as they sunk to the bottom of the water then covering the face of the country, would become intermixed with the fragments washed down from the adjoining rocks, and be consolidated like mud in a stagnant pool, acquiring additional consistency in proportion to the mass of matter superimposed.

That the volcanic action indeed was going on in this very spot, is proved by the hills of cellular lava, or of basalt, that occur in the midst of this formation; and the effects of these operations upon the tuff itself may be traced in the inclined position of its beds, so different from what would occur in a mass of matter deposited tranquilly under the surface of water.

The structure of a hill called Montecchio Maggiore near Vicenza illustrates this, as well as some other points on which I have been insisting. The rock is here composed of tuff, having fragments of amygdaloid disseminated through a paste composed of wacke. It is remarkable that this paste contains no crystalline matter, though the imbedded portions have their cells filled with calcareous spar, sulphate of strontian, mesotype, and other minerals *. On the other hand, it

* Among the Monte Berici near Montecchio Maggiore, as well as in the neighbourhood of Bassano, are found in the cavities of a cellular volcanic rock those curious geodes containing water, which have received the name

often encloses shells, which have never yet been detected in the fragments. We may therefore fairly conclude that these two sorts of rock were originally distinct; the amygdaloid having been produced by some volcano antecedent to that which gave rise to the wacke. The amygdaloid, after being thus formed into a coherent stratum by the volcano at one period, may have been broken into fragments and ejected by it at another, like the loose materials found so frequently round the craters of all active volcanos; and if a shower of ashes occurred at the same time, and had become intermixed with the fragments which then lay under the surface of water, the whole might have been consolidated into a conglomerate, possessing the appearances of the rock at Montecchio.

The materials however which compose this tuff, after being thus made to coalesce, would seem to have been brought into a more intimate union by some subsequent process, and the entire mass must be supposed to have been heaved up, and thrown upon its edges, inasmuch as the next bed of limestone rather abuts against than rests upon it.

The above imperfect description may perhaps serve to convey a general notion of the geological features displayed in this volcanic district; for a more detailed account I must refer to the works of Strange, Fortis, Marzari, and especially the later production of the Abbé Maraschini, which has been already so frequently noticed. All modern writers concur in attributing to the volcanic formation of the Vicentin a tertiary origin, and with this idea the general absence of craters, as well as the mixed character of the products, completely accord.

There appears indeed to be only one spot in which any vestiges of a crater are to be met with, namely, on the summit

of *enhydrous agates*. They appear to have been known and prized by the ancients. Pliny (lib. 37. l. 73) defines it "enhydros semper rotunditatis absolutæ, in candore est lævis, sed ad motum fluctuat intus in eâ, veluti in ovis, liquor." Propertius seems to refer to it under the name of "crystallus aquosa," "*crystallusque* suas ornet *aquosa manus*;" and Claudian has celebrated the gem in several epigrams, for it seems probable that he refers to this stone, and not to rock crystals containing water, as in Ep. 12, 13, he represents it as globular, and in Ep. 10 as convex:—

Clauditur immunis convexo tegmine rivus,
Duratisque vagus fons operitur aquis.

of a hill called Montebello, on the road between Vicenza and Verona.

But in this case, the character of the rocks that compose the mountain, so far from being basaltic, is in all respects analogous to that of recent lavas, so that the distinction between these and the other volcanic products in the neighbourhood is calculated to confirm our belief in the non-existence of craters elsewhere.

Proofs of volcanic action are not by any means confined to the immediate neighbourhood of Vicenza—they are said to extend to Verona and to Brescia, although I have no personal knowledge of the characters they present, having been prevented, when in that country, by the state of the weather from visiting them.

It is also stated, that between the Lake Lugano and Maggiore, near Grantola, pitchstone and claystone porphyry, allied to trachyte, occur. The aqueous origin of such rocks, although asserted by Beudant, is not likely in the present state of science to be admitted; but their date is probably more ancient than that of the rocks we have been considering.

Augitic rocks (melaphyres) are met with indeed on the borders both of the lakes Lugano and of Como; they were at first pronounced by Von Buch posterior to the red quartziferous porphyries, since they are in some places separated from the latter by their accompanying tuffs, which contain fragments of red porphyry; and as the conglomerate of the red sandstone of San Martino contains fragments of red porphyry, but not of the black augitic rock alluded to, which has dislocated and modified all the secondary rocks, he concluded that the eruption of the latter took place during the tertiary period.

Hoffman and Studer, on the contrary, have regarded both kinds of porphyry as contemporaneous, and believe them to have been ejected during the deposition of the red sandstone; but this difference of opinion may be reconciled by adopting the later views of Von Buch, who now considers that the black augitic porphyry of Lugano has been erupted at two successive epochs.

Lastly, on the west of the Lago Maggiore, near the town of Intra, Mount Simmolo is composed of a trap rock, which

may perhaps be connected with the preceding volcanic formation.

The above-mentioned igneous formations derive an additional interest, from being associated with those curious dolomitic rocks respecting which Von Buch has framed so remarkable a theory.

The difficulty indeed of conceiving magnesia to pervade an entire rock so intimately as is here supposed, and that too without being accompanied by any other mineral substance attributable like itself to sublimation from beneath, has caused the theory in question to find but little favour generally amongst chemists, whilst geologists themselves are embarrassed by the fact, that dolomitic limestone occurs remote from volcanic rocks, and that even when in proximity to them it often alternates with limestones entirely destitute of magnesia.

Nevertheless it is our business to report those circumstances that speak most strongly in support of a theory upheld by so distinguished a geologist, and nowhere shall we find facts more illustrative of the view taken than are presented in the neighbourhood of these Italian lakes, and in the Southern Tyrol.

To quote an instance brought forward by Von Buch, I may allude to the Lake Lugano, where we observe, first, a limestone destitute of magnesia, which, as we follow it along the lake, is found in the first place to be traversed by small veins of dolomite, then to contain crystals of the same in small cavities, next to be divided by numerous fissures, and lastly, all traces of stratification disappearing, to pass into dolomite, which becomes whiter and more granular the nearer it approaches the spot, where it gives place to augitic porphyry mixed with epidote, as at Campione, Bissone and Rovio*.

These dolomitic rocks, especially as they occur in the Tyrol, are amongst the most remarkable geological objects that have ever fallen under my notice. They present themselves often in the form of isolated pyramidal masses, many thousand feet in height, totally destitute of stratification, of a dazzling saccharine whiteness, and so steep, that they scarcely appear fit to afford a footing to the chamois, if indeed their naked sides, upon which scarcely a lichen can grow, held out any temptation for man or beast to attempt to scale them.

* See a Memoir by Von Buch, Ann. des Sci. Nat. 1827, accompanied with sections and Map, or De la Beche's Views of Geological Phænomena.

CHAPTER IX.

CENTRAL ITALY.

Central Italy.—General structure.—Volcanic rocks in Tuscany—Santa Amiata—Radicofani.—Thermal waters of St. Filippo, &c.—Lagunes near Volterra—Acquapendente—Bolseno—Viterbo—Ronciglione—Baccano—Lago di Bracciano—Tolfa.—Neighbourhood of Rome.—Alban hills.

THE volcanic phænomena of Central Italy are numerous and interesting, but I know of no detailed description of the whole district collectively considered. My own examination of it was limited to a rapid survey of a very few localities during one or other of the several journeys I have made to the south of Italy.

I must begin by reminding my readers that a chain of mountains of considerable altitude, called the Apennines, stretches from north to south through the whole extent of the peninsula. They are principally composed of calcareous rocks, which, though as compact as the Silurian or carboniferous limestones of England, are determined by their fossils to be of the same age with the chalk. Associated with these limestones are beds of greensand or Quadersandstein, occupying a considerable extent of country.

Now on the side of the Mediterranean these comparatively modern formations are seen resting on rocks regarded at the time when Brocchi wrote as transition and primitive. Not so however on the side of the Adriatic, for here the older formations seem wholly wanting, and the chalk with its accompanying sandstones are the most ancient formations brought to light.

In other respects a conformity exists between the structure of the eastern and western side of the Italian peninsula, for on both we observe a range of hills mantling round the central chain, but generally reaching an inferior elevation, which Brocchi, who first described them minutely, designated as the Subapennines. They consist of strata which Lyell has

classed partly amongst the miocene, partly amongst the older pliocene, and partly amongst the newer pliocene rocks of the tertiary period. To the miocene he refers the strata of Piedmont; to the older pliocene those of Tuscany and the greater part of Northern and Central Italy; to the newer pliocene those about Naples, Otranto and Calabria.

Now it is important to remark, that whilst volcanic operations appear to have been very frequent on the south-western range of the Subapennine hills, or at the western base of the central chain, no vestiges of the kind are to be found on the south-eastern till we reach the latitude of Naples, parallel to which, near the borders of the Adriatic, is the extinct volcano of Mount Vultur.

Hoffman suggests that this difference may be connected with the circumstance, above pointed out, of the non-occurrence of older rocks on the Adriatic side of the peninsula, a fact which seems to indicate that the uplifting cause lay nearer the surface on the western declivity of the central chain, and that the greater thickness of the alpine limestone on the opposite side controlled in a greater degree the subterranean expansive powers.

Nevertheless the destructive earthquakes that occur in many parts of the eastern side of the peninsula, as at Foligno, Perugia, and throughout the Abruzzi, may be regarded as indications that the same actions are going on on this side of the central chain also, although repressed by a greater superincumbent mass of rock.

In Tuscany, trachytes, called by Brocchi *necrolites*, compose the hills of Santa Amiata, and have been observed to traverse the supracretaceous beds near Volterra and Grosseto. At Radicofani, also in the vicinity of the Monte Amiata, and on the road between Florence and Rome, basalt occurs in rude columnar masses, covered by cellular and even scoriaceous deposits; but this too, though more modern than the tertiary marl, is of extreme antiquity, since it is only found capping the summit of the hill, which commands all the surrounding country, and is said to rise 2470 feet above the sea. What countless ages then have elapsed, since this volcanic rock formed a continuous sheet over what at the time it was erupted must have constituted the lowest level of this district!

The Monte Amiata and its dependences appear to afford the most northern exhibitions of volcanic rocks that occur on this side of the Apennines; but I must not pass over the phænomena of the hot springs in that immediate neighbourhood, nor the still more remarkable ones of the Lagunes near Volterra, both of which have a manifest connexion with the same cause.

It is my intention in another part of this work to consider the subject of thermal waters, but that which distinguishes those of San Filippo and San Quirico hard by, and gives them a claim to a separate notice, is the vast amount of calcareous matter deposited by them near the point of their emission.

The warm springs of San Filippo gush out from the Apennine limestone, which is here associated with serpentine. They contain sulphuretted hydrogen and carbonic acid gas, and deposit carbonate and sulphate of lime immediately upon issuing from the earth. It is stated that a solid mass thirty feet thick has been deposited in about twenty years from the water which supplies the Baths alone, and the rapidity with which the earthy matter is thrown down from it renders it an excellent material for forming casts, when the water is allowed to drop into certain moulds rubbed slightly over with an unctuous substance to prevent adhesion.

So great is the quantity of earthy matter deposited from the waters which flow down the hill, that there has been produced by them in the course of ages a mass of travertin one mile and a quarter in length and the third of a mile in breadth, with a thickness of 250 feet at the least, having a concretionary structure, which Mr. Lyell compares to the spheroidal forms assumed by the magnesian limestone of Sunderland.

It was interesting to remark, that sulphur, although not generally diffused through the travertin, existed in certain parts of it, in distinct nests or concretions. Now as this sulphur is evidently derived from the sulphuretted hydrogen which is a constant product of the hot waters, its limitation to certain parts of the travertin can only be explained by the tendency which all bodies have to collect round certain nuclei, by a sort of molecular attraction, which seems to act at sensible distances. At any rate the structure of the limestone deposit, and the position of the sulphur which accompanies it, are highly illustrative of the mode in which calcareous rocks have been formed at all ages, and in which have been occasioned those vast accumulations of sulphur so strikingly exemplified in Sicily.

The phænomena presented by the Baths of San Quirico or San Vignone are even more remarkable, but I must refer to the excellent account given of them in Mr. Lyell's well-known work for the particulars.

The Lagunes near Volterra exhibit appearances of a more imposing and still more uncommon nature.

They have been described by Prystanowski *, by Brongniart †, by Sir Thomas Tancred ‡, by Dr. Bowring §, by Payen || and by others.

I visited the spot in the year 1834, and determined the nature of the gases which bubble up through the water. The Lagunes are artificial pools of water, occasioned partly by the rains of which they are the recipients, and partly by the drainings from the higher parts of the country, the contents of which are probably swelled, as well as heated, by the condensation of volumes of steam, which is continually finding its way upwards through fissures in the earth into the spots where the pools have been made.

As the water in these places is raised nearly to the boiling temperature by the passage of heated gas through it, the Lagunes generally emit a lofty column of steam, which first arrests the traveller's attention, and has consequently led to the adoption of the name *Fumacchie*, by which they are often designated.

The same phænomenon is however observed in various other spots surrounding the Lagunes, especially along the bed of a neighbouring rivulet. The rock through which the steam issues is the compact limestone of the Apennines, now referred to the chalk formation, which here occurs in highly-inclined strata; in its immediate neighbourhood however, serpentine and diallage rock, the *ophiolite* and *euphotide* of Brongniart, are largely developed.

On the road from Pomerance to the Lagunes we traverse a pretty lofty and extensive hill called Poggio del Gabbro, entirely composed of ophiolite charged with diallage. On our ascent we perceived at the foot of the hill the black compact limestone, then rolled masses of ophiolite and jasper, and, lastly, ophiolite in mass. Descending the brow of Monte Cerboli towards the south-south-east, we first met

* Prystanowski über den Ursprung der Vulkana in Italien, Berlin 1822.
† Annales des Mines, 1821.
‡ Transactions of the Ashmolean Society of Oxford.
§ Bowring, Parliamentary Report on the Statistics of Tuscany.
|| Payen, Annales de Chemie, vol. i. 3rd series.

with gypsum, which here appears to rest upon the ophiolite, and in one place is surmounted by a puddingstone in thick and nearly horizontal beds, composed of various sorts of rock, and particularly of fragments of ophiolite. At a further point of the descent towards the Lagunes, we quit the ophiolite, and observe first euphotide and afterwards compact limestone in regular and numerous beds, separated one from the other by layers of marly limestone, which dip under the mountain, and consequently underlie the euphotide.

It is in this limestone that the Lagunes are situated. The steam which here rises from the interior of the earth, carries up with it, not only carbonic acid, sulphuretted hydrogen, and a mixture of nitrogen and oxygen, with rather more of the former than is present in atmospheric air, but likewise boracic acid, a product found in no other spot of Europe, excepting the crater of the island of Volcano, where also it is accompanied with similar sulphureous exhalations.

The boracic acid is found not only free, but also in combination with ammonia, which latter base is here given off in considerable quantities from the interior of the earth, and appears in combination with boracic and sulphuric acids. The soil surrounding these fumaroles is accordingly covered with a saline efflorescence, consisting chiefly of boracic acid, but likewise containing in smaller proportion certain ammoniacal salts, borate and sulphate of alumina, and persulphate of iron.

The presence of boracic acid in the steam is conceivable upon the supposition that the vapour in its passage upwards passes over deposits of this peculiar substance, for experiment shows that steam will carry up with it boracic acid in a state of mechanical suspension.

Dumas however has suggested a more chemical explanation, supposing that a deposit of sulphuret of boron exists at a great depth, and that this coming into contact with sea-water gives rise to boracic acid and sulphuretted hydrogen, the oxygen of the water uniting with the boron, the hydrogen with the sulphur.

The presence of boracic acid in these vapours was first announced in the year 1776 by Hoefer, and the manufacture of borax from this source was suggested about the same time by Mascagni. Nothing however was done to put it in practice till several years afterwards, and when at length the water had been evaporated by heat obtained by means of ordinary fuel, the quantity of boracic acid procured was too small to be a source of profit.

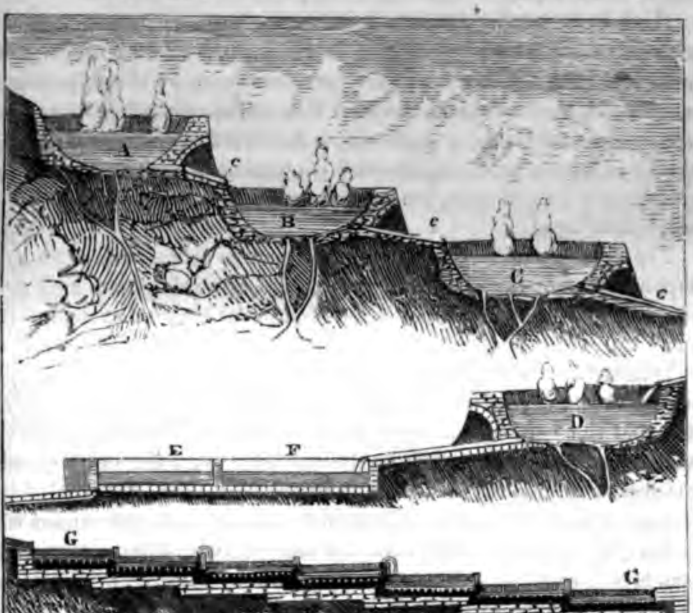
At length in 1817 a Frenchman, M. Larderelle, conceived the happy idea of applying the heat of the superabundant vapour itself as the means of evaporating the water, and at present, without the assistance of fuel, machines, or chemical materials, there is obtained

yearly, by the evaporation of eighty millions of kilogrammes of water, a produce of 1,650,000 lbs. of boracic acid, which when purified and united with soda forms a sufficient quantity of borax for the demands of nearly the whole of Europe.

The Lagunes communicate with one another by canals, so that the water that has become concentrated by the action of the steam in the one highest in the series may be transferred by opening a plug to the next, and so on in succession to the lowest, from whence it is removed to leaden pans in which the crystallization of the salt is completed.

The following woodcut will represent the arrangement of the several Lagunes by means of an imaginary section of the earth through them.

Section of the Lagunes at Monte Cerboli, near Volterra, Tuscany.



A. Most elevated Lagune.
B. Second Lagune.
C. Third Lagune.
c c c. Canals communicating from one Lagune to the next.
D. Lowest Lagune.
E. Cistern or reservoir 20 feet square, about 3 feet deep.
F. Second Ditto.
G G. Seven leaden pans, each about 9 feet in breadth and 1 foot in depth.

We must not confound with this phænomenon, which appears to be of a truly volcanic character, one occurring among the tertiary rocks of the Modenese, and in other localities hereafter to be mentioned, known under the name of *Salses* or air-volcanos. With regard to that particular locality, I shall merely state that it has no connexion with volcanic operations; and respecting its cause, shall defer my remarks until the volcanos of Sicily come before our consideration.

After leaving Radicofani we meet with no further traces of volcanic action in a southern direction till we reach the neighbourhood of Acquapendente, the intervening country being composed of marly beds belonging to the supracretaceous group, remarkable for the abundance of gypsum which is interstratified with them.

The town of Acquapendente is situated upon a precipice composed of basaltic rocks, which would seem to have been erupted subsequently to the excavation of the valley, since they descend the hill in the direction in which the river Paglia flows, resting upon a volcanic tuff. The basalt is rendered porphyritic by the presence of numerous crystals of leucite, a mineral found abundantly in the extinct volcanos of Italy, though comparatively of rare occurrence elsewhere. Von Buch imagines that a certain degree of repose in the mass during the period of cooling was necessary for its formation, a condition indeed which favours the production of all kinds of crystals whatsoever.

Thus, he says, the streams of lava that flowed from Vesuvius in 1767 and 1777 having been received in a nearly level plain between the cone from whence they issued and the Monte Somma, where their motion was very slow, contain leucite; whilst those of 1760 and 1794, which descended the slope of the mountain with greater velocity, are destitute of this mineral.

The same geologist has likewise pointed out certain facts which show very conclusively that the leucite crystals are contemporaneous with their matrix, and not formed, as has sometimes been supposed, by subsequent infiltration.

The rocks at Civita Castelletto and Borghetto contain a number of oval cavities, all of them elongated in the same direction, as must always happen in a substance which dis-

engages elastic fluids whilst its parts are in progressive motion.

Now the leucite crystals, when they intervene between the cavities, retain their usual dodecahedral figure, but where they make a part of the walls of the cells, are found to be elongated in the same direction as the latter. This last fact it is difficult to explain, except on the supposition that they were formed at the very time the lava was undergoing consolidation; for, granting that they had existed previously, it must at least be admitted that they were elongated by the heat applied, and in this case their crystalline form would have been obliterated.

The volcanic tuff continues from Acquapendente to the Lake of Bolseno, which has been imagined by some to be the crater of an extinguished volcano; and although I am disposed to question this, not only from the great size of the lake, which is more than twenty miles in circumference, but also from its form, which is rather oval than circular, yet the rocks which are scattered round its borders betray a volcanic origin.

Bolseno itself stands upon an aggregate of scoriæ, rapilli, &c. united into a kind of loose conglomerate which forms precipices overlooking the lake. Clusters of basaltic columns however occur at no great distance from the town.

The modern city stands mouldering upon the ancient Volsinium,—ruins, as Forsyth says, built upon ruins, yet both from its modern and ancient history a place of some interest.

Volsinium, it is well known, was one of the principal towns of Etruria, and the analogy of the modern name with the word Vulcan, especially according to the old spelling*, may lead us to imagine that it derived its name from the homage paid to that god, originating in the *volcanic* phænomena which excited the fears of the earlier inhabitants. It is curious that the Volsci, as well as the Volsinii, inhabited a volcanic coun-

* The old spelling of the word Vulcanus seems to have been Bolcanus. At least there is in the Vatican a Roman altar dug up at Ostia with an inscription, BOLCANO. SAC. ARA., and at Tivoli, in a wall of an ancient building, BOLCANO. AEDES. REF. COERAV. C. CAEPJO. L. F.; and there are many more that run in the same way. (See Sickler, Ideen zu einem vulc. Erd-globus: Weimar, 1812.)

try*, and it is known that particular homage was paid to *Vulcan* all over Latium†.

Volsinium therefore may have been originally written Volcanium‡, or rather *Bolcanium*, as the V and B are easily convertible, and we may recognise the original spelling in some measure restored in the modern name Bolseno. The above view however would imply that volcanic operations have occurred in the country at no very remote æra, and as this is a question of importance, it would be well if some geologist who visited that part of Italy would ascertain whether such can have been the case. Pliny mentions that Volsinium was burnt down by lightning, a statement which might possibly have arisen from its having been overwhelmed by some neighbouring volcano§; but of course until it is fully proved that there was one in action since the foundation of Rome, we can have no excuse for adopting such a conjecture‖.

* The Volsci inhabited a country between Albano and Terracina, which will be shown afterwards to be volcanic.

† See my account of the neighbourhood of Rome.

‡ Sickler suggests that Volcanus or Bolcanus may have been derived from the Greek words βῶλος, *gleba*, and καίω, *uro*; perhaps χαίνω, *hisco*, might be the more probable derivation. My learned friend Dr. Pritchard, the author of a work on the Egyptian Mythology, has however suggested to me a Celtic etymology, which he thinks more probable, as many Oscan words are derived from that language.

"The Welsh word Bwlchau or Vulchai," he says, "signifies a break in a mountain, and probably a crater, from the adjective Bwlch, broken. B is mutable into V, and from Bwlchau would be formed a Latin word Vulca, whence Vulcanus."

§ Livy mentions that the lake was tinged with blood, meaning probably bitumen (lib. 27).

‖ I have since been favoured by the authoress of the 'Sepulchres of Etruria' and other learned works on the subject of that country, with the following remarks, which I am happy to append, as supplying probably a more correct view of the etymology of Bolseno than any which my former edition had contained:—

"My idea of Bolseno does not at all coincide with yours, for there is no evidence of *my* people amongst their various sciences having ever cultivated geology. I believe them to have been *Assyrians* in the wide sense of that term, modified by Egypt, and therefore look back to those two countries for the origin of their language and institutions. I daily expect to hear that their language has been traced in Lycia, Caria, or some of the many lands of the arrow-headed character. For this amongst other reasons I believe all their *Bols*, or *Fels*, or *Bels* to be the same, and usually to have

From Bolseno to Rome volcanic tuff constitutes the prevailing substratum. Blocks of lava are however frequently scattered over the level ground, as between Montefiascone and Viterbo, and near the latter is a small lake, called *i Bulicami*, which emits an odour of sulphuretted hydrogen, and seems to be in a state of continual agitation from the rise of bubbles of gas through it.

I visited this spot in the year 1834, and found the temperature of the water to be rather above 80°, and the gas to consist chiefly of carbonic acid with a slight admixture of sulphuretted hydrogen and of common air.

Viterbo itself stands at the foot of a steep hill called the Monte Cimini, the Mons Ciminius of the ancients. Up to a certain point the hill is composed of trachyte, but as we ascend we at length meet with beds of tuff, which appear to have been ejected from an extinct crater occupying the summit of the mountain, and now converted into a lake, called the Lake of Vico.

This crater is perfectly circular, but from the midst of it rises a little conical hill, clothed with trees, the constitution of which I did not stop to examine. It would be important to ascertain whether, like the cone hereafter to be described, which protrudes from the midst of the crater of Rocca Monfina, it is composed of trachyte.

reference to בל, 'Lord,' or 'Sun.' The god *Bel* I doubt not was often Fire; hence Vulcan, the son of Jupiter. Jupiter was the Sun—the God of Heaven. But Vulcan in Etruscan was Sethlan, not Bel. The Greeks wrote the city of Vulsinia Οὐολσυνόνιον. The Rasena inscribed it on their coins F. L. S. V. N. A., written from right to left. The Ancient History turns this into פזל צנע, or 'tribe of mechanics,' because the people were excellent artisans, and celebrated for their works in bronze. I am more inclined to believe that they were בל צנע, 'the mechanics of Bel.' We have many incidental proofs in Latin translations that the Etruscans aspirated, and spoke a dialect of some purer tongue. I believe that they egyptianized Assyrian. The ancient and famous city of Felsuna was on a height, and not in its present situation. I believe that the whole region was volcanic, but that no volcano has been in action since the foundation of Rome,—perhaps I should rather say not more in action than to produce such changes as the rising of a lake (*ex. Alba*)—the darkening of the air—the subsidence of an island, &c. Many such gradual changes have taken place all over Etruria, and what was once lake is now marsh—as the Vadimonian Sea, the territory all round Viterbo, &c."

Some traditions exist in ancient writers as to the lake having been caused by a sudden sinking of the earth, in proof of which it is said, that the ruins of a town (Succinium, according to Ammianus) that formerly existed on this site might be seen at the bottom of the lake when the water was clear. These accounts however I take to be apocryphal*.

At Ronciglione the strata of tuff are cut very deeply by the action of water, forming a steep and narrow valley, highly illustrative of the antiquity of this deposit; but as we proceed towards Rome we meet with a stream of lava, hard, compact, dark-coloured and basaltic, though occasionally cellular, which is evidently of more modern date, since it follows the inclination of the valley, and may be traced to a distinct crater on a mountain contiguous, the Monte Rossi. This crater is now converted, like the preceding one, into a lake.

Lastly, on entering the Campagna we may observe at Baccano, the first post from Rome, a distinct and well-marked crater, containing within it a small lake.

Such then are the volcanic phænomena that meet our eye on the direct road from Florence to Rome, but it must of course be expected that the country on either side should present similar indications.

Not far indeed to the west of Baccano occurs a large lake, called of old the Lacus Sabatinus, from an Etruscan city Sabate, built upon its borders, but now known by the name of the Lago di Bracciano.

It is of a circular form, twenty-two miles in circumference, and being surrounded with volcanic sand, pumice and rapilli, with fragments of augite, leucite and titaniferous iron, is regarded as the crater of an extinct volcano.

Two smaller lakes which present the same characters, called Martignano and Stracciocappa, intervene betwixt it and Baccano.

Basaltic lava containing crystals of leucite crowns the heights of Trevignano and other hills in the neighbourhood. It is stated by Brocchi to be identical with the volcanic pro-

* The same tradition existed in ancient times respecting the Lake of Bracciano, probably on equally slight grounds.—Cluverius, lib. ii. cap. iii. p. 523.

ductions of the Alban and Tusculan hills, a fact which deserves to be investigated, as tending, if it were established, either to do away with the distinction between the volcanic products of the country north and south of Rome, or to prove that the rocks about Bracciano were formed in a different manner from those of its immediate neighbourhood.

As we proceed westward from the Lake of Bracciano in the direction of the sea, we meet with trachytic rocks in various places, forming hills which rise above the volcanic tuff already mentioned as overspreading the plains.

One of these hills is called La Tolfa, a spot celebrated for the production of Roman alum, which, from the time of its discovery there by John de Castro, a Greek refugee, continued to secure the preference in the market for all purposes of the arts, until the advance of modern chemistry enabled us to obtain the same material artificially in a more œconomical manner.

The production of alum at La Tolfa is to be explained by the continual rise of sulphureous vapours through the rocks, as will be more fully pointed out when we come to speak of the Solfatara near Naples. Where not acted upon by these gases, the rock of La Tolfa is a trachyte of a reddish colour, containing bright and glistening crystals of felspar, and a few scales of mica disseminated through it; but in general, from the decomposition caused by these acid vapours, it is greyish, sprinkled over with white opake spots of an earthy appearance, and containing specks of pyrites. It is in fact impregnated with the mineral called aluminite, which, as has been stated before, is a compound of alum united with hydrate of alumina. To convert this into crystallizable alum, no alkali need be added, all that is necessary being to expose the mineral to a heat sufficient to drive off the water in combination with the alumina, which latter earth becomes in consequence insoluble in water. The heated mass then being treated with water, the alum is taken up, whilst the uncombined alumina remains unaffected.

I regret being unable to add anything from personal observation with respect to these interesting localities, the state of the weather during both the visits I paid to this part of Italy having been such as to prevent me from extending my researches beyond the immediate line of my route.

The same cause also contributed to circumscribe my excur-

sions in the neighbourhood of Rome during the stay which in the year 1823 I made in that city, where indeed, it must be confessed, the traveller, surrounded as he is by antiquities of such extreme classical interest, can hardly help being frequently called away from subjects of scientific inquiry*. It has been said, that what Vesuvius is to Naples, the Coliseum and St. Peter's are to Rome; and as the scholar almost necessarily imbibes somewhat of the spirit of a naturalist during his stay in the former city, from his attention being so frequently directed to the movements of the volcano; so it is equally to be supposed that the study of nature will give place to that of art, whilst we are in the midst of the monuments of Roman taste and magnificence.

I saw enough however of the physical structure of the neighbourhood to be persuaded, that the interpretation which Breislac† has put upon some well-known fables or traditions

* I have corrected and enlarged the brief sketch of the neighbourhood of Rome, which my own observations had chiefly enabled me to supply in the first edition of this work, by reference to Frederic Hoffman's Essay appended to Bunsen's 'Beschreibung der Stadt Rom,' a paper of his on the Alban Hills translated in Jameson's Journal for 1832, a Memoir in the same Journal for 1833, and Sir W. Gell's 'Topography of Rome.'

† Breislac, in proof of his opinion as to the existence of volcanos on the site of Rome, appeals to the worship especially paid to Vulcan, whose temple, according to Plutarch and Dionysius of Halicarnassus, overlooked the Forum. This spot he supposes to have been affected by the same agent even subsequently to the foundation of the city, for the chasm in the midst of the Forum, into which Marcus Curtius precipitated himself, was probably caused, if we believe our author, by volcanic action.

The principal crater he supposes to have existed in the circular space between the two summits of the Aventine, where the church of St. Balbina now stands, and the fable of Cacus, whose cave stood on this hill, furnishes him with a confirmation of this opinion.

The description given by Virgil of this mountain applies very well to the picture of the phænomena of a volcano :—

Huic monstro Vulcanus erat pater. Illius atros
Ore vomens ignes, magnâ se mole ferebat.
....
Faucibus ingentem fumum, mirabile dictu,
Evomit, involvitque domum caligine cæcâ,
Prospectum eripiens oculis; glomeratque sub antro
Fumiferam noctem, commixtis igne tenebris.

And

handed down to us by ancient writers, in proof of his idea that ancient Rome occupied the site of a volcano, is altogether untenable, and that his assertion as to the Capitol of the eternal city—"*Capitoli immobile saxum*"—having been erected on the tottering edge of a crater, however well-suited it may be to point an antithesis, or to illustrate the vanity of human pretensions, rests on too slender grounds to deserve a place in a scientific treatise.

The soil of Rome, as an eminent Italian geologist* has since fully proved, is in reality composed of an alternation of sandy or calcareous beds, with a tuff containing fragments of scoriform as well as compact lava, often rolled, and accompanied likewise with pebbles of the Apennine limestone, that display evident marks of attrition. There is however no proof that these fragments of lava were ejected by any volcano which occupied the immediate site of Rome; on the contrary, the nearest spot from which we can suppose them to be derived is the Lake of Albano, more than twelve miles distant.

And his account of the cave corresponds equally with the idea of a crater:—

> At specus et Caci detecta apparuit ingens
> Regia, et umbrosæ penitus patuêre cavernæ.
> Non secus ac si quâ penitus vi terra dehiscens
> Infernas reseret sedes, et regna recludat
> Pallida, Dîs invisa, superque immane barathrum
> Cernatur, trepidentque immisso lumine Manes.

Virgil also mentions a tradition respecting the Capitoline hill, which Breislac converts into an allegorical representation of volcanic phænomena:—

> Hinc ad Tarpeiam sedem et Capitolia ducit,
> Aurea nunc, olim silvestribus horrida dumis.
> Jam tum religio pavidos terrebat agrestes
> Dira loci; jam tum silvam saxumque tremebant.
> Hoc nemus, hunc, inquit, frondoso vertice collem,
> Quis deus, incertum est, habitat deus; Arcades ipsum
> Credunt se vidisse Jovem, quum sæpe nigrantem
> Ægida concuteret dextrâ, nimbosque cieret.

It is a pity that so many ingenious analogies should be thrown away, but the existence of a volcano on the spots alluded to is quite irreconcilable with their known physical structure.

* Brocchi, Suolo di Roma, 1820.

But the differences of mineralogical character between the volcanic rocks of the Alban hills and those found about Rome itself, oblige us to abandon the idea that the latter can have been derived from the same quarter. The hills in the immediate vicinity of that city consist of that aggregate of volcanic materials which all are agreed to designate as tuff, whilst the neighbourhood of Albano is constituted of a material which the Italian geologists have chosen to mark as a separate rock under the name of Peperino*. It is easy, says Von Buch†, to distinguish these two substances; in Peperino nearly the whole mass is fresh, undecomposed, and bright to the eye, whereas in Tuff the greater part is dull and appears weathered. The former resembles a porphyry, the latter a sandstone and other similar aggregates. The substance of which Peperino consists preserves almost uniformly an ash-grey colour, but the Tuff of Rome is generally darker. With respect to its fracture too, Peperino is less friable than Tuff, and the mica, whether it be distributed over it in detached plates, or is collected into masses which are of various sizes, sometimes as large as a cannon-ball, and are mixed with crystals of augite and magnetic ironstone, ever preserves its original black colour and lustre, which is not the case in the Tuff.

A still more marked difference perhaps between the two formations is the entire absence of pumice from the neighbourhood of Albano, although so frequent in the tuff about Rome.

The latter therefore seems with more probability referable to the chain of volcanic mountains north of Rome, already described under the name of the Monte Cimini, since we find on the slope of these hills similarly constituted beds, to which indeed, according to Brocchi, the tuff of Rome may be traced without interruption.

The characters of this rock in both localities correspond with those of the tuff of Auvergne and of the Vicentin, rolled masses and shells being occasionally found in it; so that, although the materials of which the aggregate is composed are chiefly volcanic, the rock itself betrays marks of a mechanical

* See Brocchi, Catalogo Ragionato, *passim*.

† Reise durch Deutschland und Italien, Berlin 1809, vol. ii. p. 70.

origin. Like the tuffs before noticed, it contains mica, augite and felspar, but is distinguished from them by the presence of leucite, which rarely however preserves its lustre and crystallization, but is generally more or less decomposed and of a mealy consistence.

Brocchi* distinguishes two principal varieties of this tuff—lithoide, found at the Capitoline and the Esquiline hills, and granular, met with on the Pincian and Quirinal.

Lithoide tuff is generally of a reddish-brown colour, with specks of a darker or orange tint derived from fragments of scoriform lava, approaching in texture to pumice. Its fracture is earthy in the small, conchoidal in the great, and its hardness sufficient for a building-stone, for which purpose it was employed by the ancient Romans. It appears to be the *lapis quadratus* employed in paving the streets and in the construction of houses during the early times of the commonwealth. The Cloaca Maxima is built of it, as is part of the under-structure of the Tabularium of the Capitol.

Granular tuff, on the contrary, is generally of a blackish-brown, dark violet, or russety yellow colour. It is light, friable, and composed of largish grains, weakly cohering, having white specks of mealy leucite disseminated over the mass, together with fragments of augite, scales of mica, and rolled pebbles of grey or black lava. It is in short nothing but an aggregate of lapilli, and by its decomposition it gives rise to the only other variety, which is distinguished by Brocchi under the name of earthy tuff.

The origin of all this formation must have been antecedent to the draining off of the waters which formerly rendered the site of Rome a freshwater lake. This is evinced, not only from the valleys by which its once continuous beds are at present intersected, but likewise from the Neptunian deposits with which it is seen repeatedly to alternate. The principal of these is either a sandy marl containing fragments of older rocks, or that calcareous deposit known under the name of Tiburtine or travertine stone, so called from its being found at Tivoli, the ancient Tibur, which has furnished the material for most of the edifices of ancient as well as modern Rome.

The principal masses of this curious limestone lie in horizontal beds, have a yellowish-white colour, uneven fracture, and earthy grain. They are remarkable for the numerous perforations and cavities which pervade their mass, sometimes tubular, arising from stems of plants, &c. which have decayed; sometimes irregular, occa-

* Suolo di Roma.

sioned probably by the escape of gaseous matter through them. They also are frequently moulded into a series of spheroidal concretions, with concentric coats varying in size from that of a pea to several feet in diameter, as is well explained by Mr. Lyell*.

This rock, it may be observed, is not produced by the waters of the Tiber at the present moment, but we have ocular proof of the manner of its formation in the Lago di Solfatara, near Tivoli, where the same process is constantly going on. The water is there impregnated with sulphuretted hydrogen and carbonic acid gases, which rise up in bubbles through it, and to the presence of the latter substance it owes its property of dissolving calcareous earth, which is again deposited round the lake in the form of travertine, in proportion as the carbonic acid escapes.

The same process appears to have taken place formerly on a much more extensive scale in the neighbourhood of Rome, and, if we are disposed to theorize, we may attribute it to a more abundant disengagement of these two gases at a period not so far removed from that at which the volcanos of the neighbouring country were in activity. For it will be seen as we proceed, that the extrication of elastic fluids, of which sulphuretted hydrogen and carbonic acid are the most common, takes place round the site of a volcano long after the cessation of its more violent action, so that there is no absurdity in supposing that the same operations, which when in their greatest intensity produced the materials of the volcanic tuff itself, may during the periods of their partial intermittence have given rise to these gaseous exhalations, which imparted to water impregnated with them their property of dissolving calcareous matter; nor will analogies be wanting to support us, if we assume that a feeble remnant of the same action even at this distance of time continues, and manifests itself in the sulphureous exhalations near Tivoli.

It would appear, that these indications (if they may be so considered) of languid volcanic action were more extensively distributed about the neighbourhood at earlier times than at the present. Thus Varro makes mention of warm baths near the temple of Janus, whence the spot obtained the name of *Lautolæ* "*à Lavando*;" a spot on the Esquiline hill was called *Puticulæ*, from the sulphureous smell which it emitted; the legend, if it be no more, of the leaping of Curtius into the gulf, at least shows that the early Romans were familiar with phænomena to which a volcanic origin may probably be ascribed; and the wood consecrated to the goddess Mephitis renders it probable that a noxious gas arose from that place. All these have now

* Principles of Geology, vol. i. p. 208.

ceased, and nothing remains but the Lago de Solfatara to remind us of their existence.

It is remarkable that no kind of animal is seen near this water, a circumstance which can only be attributed to the noxious qualities of the sulphuretted hydrogen, for the Lago de Tartaro near, so well known for its calcareous incrustations, contains abundance of molluscæ. Shells are also in general rare in the ancient travertine near Rome, although they occur abundantly in a few localities.

The existence of masses of this latter substance on the very summits of the Seven Hills proves, that at the period of its formation the site of Rome must have been covered with water to the depth of at least 140 feet.

From the character of the shells sometimes contained in the travertine, as well as in the argillaceous and calcareous sand, shells which Brocchi has ascertained to belong to existing species, we may conclude that the water which deposited it was not impregnated with salt, and are consequently enabled to fix the date of the volcanic tuff which accompanies these Neptunian deposits, as corresponding with that of the latest freshwater formation.

One circumstance of considerable interest connected with these deposits is the occurrence in them of bones of elephants and of other land animals, as on the Pincian hill, on the summit of Monte Verde covered with calcareo-siliceous sand, in the Mons Sacer at the depth of thirty feet, near Monte Mario covered by travertine containing freshwater shells, at the foot of the Vatican, and in numerous other localities.

Thus the phænomena presented by these, the newest strata in the vicinity of Rome, imply nothing more than the existence on the spot now occupied by the city of a lake of fresh water, contemporaneous with the ejection of scoriæ and rapilli from the volcanic vents in the neighbourhood.

Vestiges of this lake seem to have existed even so late as the building of Rome, for that low part of the city between the Aventine, Palatine and Capitoline hills, called the Velabrum, was occupied by water, until drained by the construction of the Cloaca Maxima in the time of the Tarquins. Thus Tibullus—

At quâ Velabri regio patet, ire solebat
Exiguus pulsâ per vada linter aquâ.

Brocchi has however shown that the beds above noticed rest upon a formation sometimes containing marine shells. It consists either

of a yellow sandstone or of a conglomerate, both which are incumbent upon a mass of bluish marl, used for pottery by the ancients*, and found under the Vatican and in other neighbouring localities.

The chain of hills on the right bank of the Tiber is chiefly composed of these oceanic deposits, and the Monte Mario, the highest point of this range, contains numerous Oysters, Patellæ, &c. No doubt it underlies the freshwater beds seen on the left side of the river.

The great mass of volcanic tuff near Rome rests immediately upon this marine formation, but as it likewise alternates with the freshwater beds incumbent, it must in this neighbourhood be regarded as a deposit from inland lakes, and not from the bed of the ocean.

To the south of Rome the whole of the country for several miles round Albano abounds in volcanic appearances. Amongst the mountains in this group are several lakes which appear originally to have been craters, as for instance that of Albano, Vallariccia, Nemi, and Juturna, to which we may add, intermediate between the Alban mountains and the Anio, the Lake of Gabii, noted for a particular variety of Peperino called the Gabian stone, and the singular hexagonal one of Cornufelle, near Frascati, supposed by Gell to be the Lake Regillus.

The Lake of Albano, one of the most beautiful pieces of water in the world, is about six miles in circumference, entirely surrounded by beds of the Peperino already described. Owing to the Emissario or tunnel by which the waters were partially carried off in the time of the Romans†, the level of the lake is now 200 feet lower than it had been antecedently to that undertaking.

The Lake of Ariccia or Vallariccia is a deep hollow, eight miles in circumference, situated about a mile from Albano, which although now dry was filled with water so late as the time of Strabo. In proof that the volcanic action had not entirely ceased even in modern times, I may state that Pliny mentions a report which had reached him as to the ground

* "Et Vaticano fragiles de monte patellas."

† It was cut, according to Livy (lib. v. c. 15), by the Romans during the siege of Veii, in compliance with the injunctions of an oracle, which assured them that the city would never be taken until the lake had its water drawn off.

round the lake being hot enough to set fire to charcoal*; and Livy notices a shower of stones that fell there, as well as the bursting out of a warm spring, having its water mixed with blood, which Heyne supposes to have been bitumen†.

There are indeed some passages in ancient writers, which might lead us to suppose a volcano to have existed among these mountains even at a period within the limits of authentic history, for Livy notices a shower of stones which continued for two entire days from Mount Albano during the second Punic war‡, and Julius Obsequens in his work 'De Prodigiis' remarks, that in the year 640 A.U.C. the hill appeared to be on fire during the night §.

There are likewise several other traditions preserved by classical writers which speak to the same point, one of them relating to a king of Alba, Aremulus Sylvius, who, according to some accounts, was precipitated, together with his palace, into the Alban lake by an earthquake, and according to others carried into it by a whirlwind after being struck dead by a thunderbolt ||.

These accounts indeed, if not confirmed by other testimony, might be rejected as fabulous, but they may perhaps suffice to establish the comparatively modern date at which the volcanic action continued, when viewed in connexion with the physical structure of the lake itself.

The quiet and sequestered Lake of Nemi is about three miles beyond that of Aricia, lying immediately under the town of Genzano. The regularity of its outline, and the character of the materials encircling it, which agree with those of the surrounding country, impress upon the mind the idea of its having been once a volcanic crater, an inference however which is disputed by Hoffman both with regard to this and the other lakes of the Alban hills, for he regards them all as mere sinkings in the earth, on the ground that the strata are not continuous round the margins of the cavity.

* Plin. Hist. Nat. lib. ii. c. 111.

† Heyne, Opusc. Acad. vol. ii. p. 263.

‡ "Albano monte biduum continenter lapidibus pluit." (lib. xxv. cap. 7.)

§ "Mons Albanus nocte ardere visus."—Julius Obs. c. 110.

|| Aurelius Victor de Origine Gentis Romanæ.

The Lake of Juturna* lies about six miles from Nemi, near the foot of the Alban hills. There still exists a fountain, which may be the same to which medicinal qualities were ascribed by the ancients, and a little stream issues from it which flows into the Tiber.

This however, and the other lakes above-mentioned, if even they be considered as volcanic craters, are but the dependencies and offsets, as it were, of the great extinct volcano, the traces of which still remain upon the summit of the Alban hills.

The configuration of this mountain reminds one much of what I shall have to describe when speaking of the relations of Vesuvius to Monte Somma. There is an outer circle of volcanic rocks consisting of peperino which stretches in a crescent-form from above Frascati to Monte Porzio, Rocca Priore, and Monte Artemisia. The side fronting Rome seems to be broken away and destroyed. Within this great inclosure, near the romantic site of the village of Rocca di Papa, is another crater-shaped cavity, the walls of which are basaltic and constitute the heights of Monte Cavo, the most elevated point of the Alban hills, stated by Boscovich to be nearly 3000 feet above the level of the sea. This was the eminence from which Virgil describes Juno as surveying the contending hosts of

* The fountain of Juturna is noticed by Servius, Varro, and others, the lake by Propertius, who records a tradition which relates that the Dioscuri, after succouring the Romans at the battle of the Lake Regillus, quenched their horses' thirst in its waters:—

Albanusque lacus socii Nemorensis ab undâ,
Potaque Pollucis nympha salubris equo.
Lib. iii. eleg. 20.

Livy however gives this honour to the well of the temple of Vesta, in the Forum at Rome itself:—

On rode they to the Forum,
While laurel-leaves and flowers
From house-tops and from windows
Fell on their crests like showers.
When they drew nigh to Vesta,
They vaulted down amain,
And wash'd their horses in the well
That springs by Vesta's fane.

Turnus and Æneas*, and a more commanding post could not have been selected for the purpose, embracing as it does within its ample horizon the whole expanse of the Campagna, with Rome in its centre, the line of coast as far as Civita Vecchia, and the range of the Sabine hills.

The crater of Monte Cavo also is broken away on the side looking towards Rome, but the semicircular form is complete towards the east, and the interior of the cavity is occupied by flat meadows, supposed by some to have been the camp of Hannibal, and known at present by that name.

Between the inner and outer circus is the valley, called by Livy *Vallis Albana*, which bears the same relation to the double crescent of hills between which it is placed, as the Atrio del Cavallo does to the Monte Somma and the cone of Vesuvius.

Hoffman†, in conformity with the views of Von Buch, suggested that the outer crater of Mount Albano, which, as we have seen, consists wholly of peperino, has been upheaved from the interior of the earth, in the same manner as we have conceived the mountains of Cantal and of Mont Dor to have been formed, whilst the inner crater he regards as produced by eruptions of basaltiform lava, like Mount Vesuvius at the present day. From the side of the latter, looking towards Rome, appear to have proceeded two streams of lava, one of which terminated on the Appian road near the mausoleum of Cæcilia Metella, where it forms a little rising ground called Capo di Bove, whilst the other reached the road to Ardea, near Vallerano (Villa Aurelia ?).

The former of these *coulées* is usually compact, though small cells and cavities are here and there scattered over it, especially near its surface. It is very hard and sonorous, and appears to consist of an intimate mixture of augite and leucite, either in crystals or granular masses, the former of a bottle-green colour passing into brown, the latter white or azure.

Besides the above, the rock of the Capo di Bove contains several other minerals which may be regarded in the light of accidental ingredients.

---

* At Juno e summo, qui nunc Albanus habetur,
(Tum neque nomen erat, nec honos aut gloria monti)
Prospiciens tumulo, campum adspectabat, et ambas
Laurentum Troumque acies, urbemque Latini.

† Edinb. New Phil. Journal, 1832.

Amongst these, according to Brocchi*, are—black dodecahedral crystals with rhomboidal planes, the nature of which is not determined; melilite, pseudo-nepheline, mixed with which two latter minerals, are, fine thread-like crystals of a white colour, which melt before the blowpipe into a vitreous or opake globule, emitting a phosphoric light, and which are also called by Hauy pseudo-nepheline.

There are moreover other needle-shaped crystals of a brown coffee colour, or of a lively red, which exposed to the air lose their natural colour, and become first yellow and afterwards white. Before the blowpipe they melt into a blackish globule, and upon the whole are regarded as the same with some found by Breislac† in the crater of the Solfatara near Naples, which have been named in honour of him.

Brocchi likewise has noticed nuclei of various sizes made up of a semitransparent substance, with a lamellar structure, greyish colour and pearly lustre, which is probably table-spar. Calcareous spar is likewise found, as well as the substance, called abrazite by Gismondi, and distinguished by its octahedral crystallization, by not effervescing with acids, and fusing without ebullition in the flame oi a candle.

The breadth of this current near its termination at the tomb of Cæcilia Metella is sixty feet; it rests on rapilli and tuff, and may be traced along the plain up to the hills about Albano from which it has proceeded.

The other streams of lava which occur about the Alban hills have not been particularly described; two are said to exist between Colonna and Monte Porzio, two others between Monte Porzio and Tusculum, and one near Tusculum which may be traced into the valley below Frascati.

---

* Biblioteca Italiana, vol. vii.

† Breislac, Campanie, tom. ii. p. 132.

CHAPTER X.

SOUTHERN ITALY.

General remarks on the volcanos of Southern Italy.—Rocca Monfina—its position described—ancient site of the Aurunci—history of that people—structure of the mountain—nature of the rock which protrudes through the centre of the crater—inferences as to the mode in which the mountain itself must have been formed.—Ponza Islands.—Structure of Ponza—Palmarola—Zannone—Ventotienne—San Stefano.—General remarks.

UNDER the head of Southern Italy I propose to comprehend the whole of the kingdom of Naples. We there see presented to us no less than three distinct systems of volcanic formations, which are sufficiently contrasted one with the other to exemplify as many different phases or conditions of igneous action.

The localities to which I allude are—1st, the neighbourhood of Sessa, near the northern boundary of the Neapolitan territory towards the Mediterranean; 2ndly, that of Melfi in Apulia, in the vicinity of the Adriatic; and 3rdly, the country immediately surrounding Naples itself.

The two former of these localities I had not visited at the time when the first edition of this work appeared, and consequently the description therein given of them was not only meagre, but also in several points inaccurate.

Having however during one of my subsequent visits to Italy personally examined the second of these, I mean Mount Vultur, and during another the first, namely Rocca Monfina, I am now enabled to supply these deficiencies, and to convey to my readers, as I hope, a more correct idea of the nature and relations of these two remarkable mountains than I could formerly have done.

On the road between Rome and Naples, the first indications of volcanic action, after passing the Pontine Marshes, occur a little to the south-west of Mola de Gaieta, near the river Garigliano, the ancient Liris. We there find ourselves be-

tween two ranges of hills; that to our right the Monte Massico, composed of the Apennine limestone, the other on our left, Rocca Monfina, consisting entirely of volcanic materials.

The town of Sessa, the "Suessa Auruncorum" of the Romans, stands itself just where the latter mountain commences, its narrow streets being built up the slope of the mountain of Rocca Monfina, at the foot of which it is situated.

In my former edition I had stated, on the authority of Breislac, that the ancient city was covered by the volcanic tuff of the mountain, which would imply that the latter had been ejected during the historical period, but this upon subsequent examination I found not to be the case.

There are indeed near the upper part of the town, a little to the left of the principal street, the remains of an amphitheatre, and a long vaulted chamber covered within with stucco, and apparently filled up to a distance of only five feet from the ceiling with rubbish. The above buildings may, as Breislac represents, have been covered over by the tuff which forms the material of the precipitous mountain above them, but this is very conceivable, without imagining them to have been enveloped, like Pompeii, by a shower of volcanic dust from any eruption subsequent to their erection. At any rate, I could discover no satisfactory proof which should outweigh the great antecedent improbability of such an event having occurred.

The mountain of Rocca Monfina then is bounded on the south-west by the town of Sessa, whilst on its eastern declivity nearly at the same level stands the little town of Teano, the ancient Teanum. Both these cities will be familiar to the readers of Livy, the first as Suessa Auruncorum, the last hold of the Aurunci, the second as the seat of the rival state of the Sidicini; and it may be interesting and not altogether irrelevant to the subject of this work, to state briefly what is known of the history of the former people, so far as it has any reference to the mountain we are now considering.

The Aurunci then, in the earlier periods of Roman history, seem to have had their capital at the summit, and not on the declivity of Rocca Monfina; and though it may be true that they possessed themselves at one time of a considerable tract in the level country both of Campania and of Latium, yet their original site was the hilly district intervening.

Thus they are noticed by Virgil as a hardy race of mountaineers—

> ——— et quos de collibus altis
> Aurunci misere patres.

and those who like myself have ascended the mountain, will regard it as admirably well-adapted for the stronghold of a warlike and predatory clan.

We first read of them indeed soon after the expulsion of the Tarquins, as having formed a confederacy against Rome with two Latin cities, Pometia and Cora, when being defeated with great slaughter, they are said to have taken refuge within the walls of Pometia. The following year Pometia was besieged without success, and one of the consuls being severely wounded, the invading army sounded a retreat.

A second army was however quickly despatched, and Roman perseverance at length triumphed, Pometia being taken by assault; after which it was so completely destroyed, that though it had ranked as the principal town in the Pontine Marshes, to which indeed it gave its name, no vestige of it can now be discovered, and its very position is unknown.

Still the Aurunci remained unmolested in their capital on the summit of Rocca Monfina, to which the Romans, as it would appear, did not think it prudent to pursue them; and although a few years afterwards, when this same people, in consequence of the taking of the town of Suessa by the Romans, joined the Volscians, they were again defeated in battle, their independence was still preserved to them within the range of the mountain fastness alluded to.

For the next century and a half the Aurunci appear to have kept aloof from collision with the Roman power, but in the year A.U.C. 410, they made a predatory incursion into the Roman territory, which excited so much alarm from the fear, lest, if unchecked, the whole Latin nation might rise and make common cause with them, that a dictator was appointed to head the army sent to oppose their march. They were indeed promptly repulsed, but nevertheless, in the great Latin war which commenced about five years afterwards, they again took part against the Romans, and shared in the defeat which attended the arms of the confederates.

At the peace which followed, they were admitted into the alliance of the Romans; but from this moment may be dated their ruin, for soon afterwards the hostile nation of the Sidicini, either by surprise or treachery, effected that which the Romans appear never to have attempted, namely the expulsion of this people from their stronghold on the summit of Rocca Monfina, which, with its walls and

fortifications, was utterly demolished, the inhabitants being compelled to seek refuge in the town of Suessa, the modern Sessa, in the plain below.

After this event, all we read of the Aurunci is, that they took part with the Samnites in their second war against the Romans, and in consequence of their defeat were obliged to submit to receive a Roman colony, so that their existence as a separate state was from this period destroyed.

That they should so long have resisted the Roman power, and not been finally subdued until deprived of their original fortress on the top of Rocca Monfina, will be less a matter of surprise when I have described the structure of this remarkable mountain.

After a rather steep ascent of about 2000 feet, we find ourselves all at once within a very regular crater, the brim of which is perfect on the west, where it forms the lofty and precipitous Monte Cortinella, and may be traced in other parts throughout its entire circumference, except on the side which we enter on coming from Sessa, where it is so far broken away, that there is scarcely any sensible descent before arriving within its precincts. The circular form and extent of the crater are however better observed from some point near to its centre than from its margin, and a remarkable conical protuberance which rises up from the midst of the crater, and reaches an elevation of 3200 feet *, considerably exceeding the highest point which the margin of the latter attains, gives us an excellent opportunity of surveying its internal dimensions.

Its diameter is estimated at two and a half Italian miles, and its circumference at seven and a half, but a large portion of its interior is occupied by the conical hill above noticed.

Thus we can hardly imagine a position better calculated for the stronghold of such a nation as the Aurunci are described to have been.

Their outpost Suessa, situated as we have seen near the bottom of the mountain, commanded the approach to it on that side where it was most accessible, and secured to them a communication with the sea, with the cities of the Pontine Marshes, and with their possessions in Campania.

If driven from thence, they had only to retreat to the summit of the mountain, where, posted on the external margin of the crater, they might watch the movements of any invading force, long before it could gain the top of a mountain of such height and so difficult of access. In case of an attack, they could drive their flocks and herds

* Abich, über die Natur, &c. der vulkanischen Bildungen. Braunschweig, 1841.

within the crater, where they would find ample space and good pasturage without danger of molestation, unless indeed the invading force were powerful enough to dislodge them from the vantage ground which their army would occupy on the brim of the crater, itself a natural fortress, inclosing within its ample boundaries a large tract of fertile land.

Even if forced to relinquish this stronghold, they still had it in their power to take refuge on the conical and precipitous mountain which rises up from the very centre of the crater, where a small force might easily set at defiance a host of invaders.

On this mountain, called, from a cross which till lately stood on its summit, the Monte della Croce, they accordingly appear to have placed their citadel; for an Italian archæologist* first pointed out on a level spot nearly at the top of this eminence, as vestiges of the ruined city, pavements of streets, corners of apartments, foundations of buildings, three cisterns for containing water, together with heaps of hewn stones, and remnants of very strong walls.

Some of these were perceived by myself in the course of my rambles over the mountain, and I found that they consisted of the same material which composes the rock on which they had been erected.

No better proof than this could be adduced of the antiquity of the volcanic operations to which the mountain owes its actual configuration; for, as Sir William Gell observed to me, when I once descanted with him on the extreme disproportion which exists between the length of period embraced within the several epochs of human and of geological history,—a nation like the Aurunci, to whom it was of essential importance to have near their city good pasturage for the flocks and herds on which they depended for support, would never have selected Rocca Monfina for their capital, not only if the volcano itself had been in activity, but had not the stone which constitutes the interior of the crater been already in such a state of decomposition, as to be covered with herbage, and to yield abundant crops†.

With regard to the geological structure of the mountain I may remark, that with the exception of the conical mass of rock in its centre, which constitutes the Monte della Croce, it is almost entirely composed of beds of volcanic tuff, which

* Perotta, Sede degli Aurunci, as quoted by Romanelli, vol. iii. p. 444.

† See my Memoir 'On the Site of the Ancient City of the Aurunci, and on the Volcanic Phænomena which it exhibits.' Transactions of the Ashmolean Society, 1846.

differs however from that met with round about Naples, in the inferior degree of its compactness, in its more earthy appearance, in the more frequent presence of mica, and the rarer occurrence of the darker varieties of pumice.

I remarked a red ferruginous variety of tuff, sometimes in beds alternating with the commoner kinds, and in one instance forming a kind of vein running vertically through the strata.

The tuff continues from the town of Sessa till we approach the outer brim of the crater, covered over with loose uncompacted aggregates of volcanic sand, and of stones promiscuously heaped one upon the other.

In this tuff are often imbedded not only its usual concomitants, sand and rapilli, but also large blocks of a kind of porphyry, peculiar as it would seem to the products of the ancient volcanos of Monte Somma and of Rocca Monfina in the Neapolitan territory, and of Acquapendente and Viterbo in the Roman, characterized by crystals of leucite, which at the spot now under consideration are often of extraordinary dimensions, sometimes two inches and a half in diameter, and are accompanied by minute crystals of augite, both imbedded in a felspathic basis. As the felspathic portion was more readily decomposed than the imbedded crystals, these latter might often be detached from their matrix in a state of great integrity.

Near to the little village of Tuoro de Sessa, which is situated very little below the external margin of the ancient crater, we observe a continuous bed of this leucitic porphyry, resting upon the tuff, and extending for some distance along a ravine which runs obliquely down the sides of the mountain. This was the only instance that occurred to me, in which the above rock appeared in any other form than that of detached blocks.

The most remarkable feature however in the physiognomy of this mountain, and that which distinguishes it from most other volcanos, is the protrusion from the interior of the crater of a conical mass of a rock resembling trachyte*, large

* See Plate I., for the Section and Ground Plan of Rocca Monfina, the former reduced from a sketch taken by the artist who accompanied me on my visit to the mountain; the latter borrowed from a Memoir by Professor Pilla, who however has represented the crater as though it were entirely effaced on the east, whereas it appeared to me there distinctly traceable, although undoubtedly much lower than it was on the west.

enough to fill up two-thirds of the area comprehended within the walls of the crater, and so lofty as to rise considerably above the most elevated point in its margin, constituting indeed, when observed from a distance, the most conspicuous object embraced within the compass of the mountain.

This trachytic rock is much more abrupt than the tuff through which it appears to have been protruded. In its centre is a hollow plain, which may possibly have once been a kind of crater, as there are still on three of its sides points of rock that rise considerably above the central concavity, of which the highest was formerly marked by a cross; a circumstance which, as I have stated, served to give the name of Santa Croce to the entire mountain.

The rock is generally of a reddish brown colour, its base sometimes grey, fine-grained and compact, but not of very close texture, intimately interwoven with small felspathic portions, which frequently show a glassy fracture, as if from fusion.

Much green augite, never however accompanied by even a trace of hornblende, penetrates the whole mass, and brown mica, generally in hexagonal tables, is a predominant ingredient. Abich regards the rock in the aggregate as forming a link intermediate between trachyte and greenstone, and therefore denominates it *trachyte-dolerite*. He conceives it to contain neither albite nor glassy felspar, but oligoclase. The most distinguishing characteristic of the stone is the confused manner in which its mineralogical constituents are intermixed.

Pilla informs us that the summit of this cone is exactly equidistant from all parts of the crest of Monte Cortinella, the only portion of the original crater that stands absolutely intact, showing that it stands just in the centre of the inclosed area; a singular and improbable coincidence, unless it had upheaved the rest of the mountain, but one presenting no difficulty if we admit this supposition.

The rock alluded to, abrupt as it is, seems to be everywhere covered over with vegetation, and a fine chestnut forest occupies a considerable portion of its flanks.

From its summit the eye embraces, on the one hand, Mola di Gaieta, the range of mountains terminating in Cape Cir-

cello, and the whole extent of coast as far as Ischia and Vesuvius; whilst on the other, the line of the Apennines, including the monastery of Monte Casino, and other places built upon the slope of these mountains, appears conspicuous.

Now the circumstance which in a geological sense attaches the highest interest to the structure of this mountain, is the support it seems to afford to the *theory of elevation*, in the protrusion of this compact mass of trachytic rock through the centre of a mountain mainly consisting of materials so different from it as leucitic porphyry and volcanic tuff, and in its attaining moreover a height so considerable as it has done in the instance before us.

The first difficulty in the way of supposing it formed by the same operations as those which produced the mass of the surrounding mountain, arises from the constitution of its component parts, which is such as to imply a different origin for the two, the felspar of the central cone, according to Abich, being oligoclase, which contains but little potass, whilst the tuff is charged with leucite, which abounds in it.

Moreover it may be argued, that if the Monte della Croce had consisted of heaps of incoherent scoriæ, or of large fragments of slaggy lava piled one above the other, like the cone which is now forming in the centre of the crater of Vesuvius, its existence might then indeed have been explicable by an appeal to the every-day operations of which we are eye-witnesses in volcanos now in activity—that had it even formed part of a stream of lava, which might still be traced down the external flanks of the mountain, although we should have wondered at its ample dimensions, we might nevertheless have referred it to the same cause; but that a conical mass of rock so considerable, and yet so completely circumscribed within the area of the crater, could only, as it would seem, have been brought into the position which it is seen to occupy, by being upheaved *all at once* from the interior of the globe, whilst in a semi-fluid or pasty state, but not in a condition of actual liquidity.

We have therefore before us an agent, which would not only be competent to uplift the surrounding strata of tuff, but which must necessarily have done so, if the latter had been at the time of its eruption in a horizontal position;

and to suppose them gradually formed by successive showers of loose incoherent ejected materials, before the trachytic rock in its centre was protruded, seems to imply a forgetfulness of the height which the tuff has attained, and of the high angle at which its beds are inclined.

Alternating strata of tuff and lava may indeed be imagined to build up in the course of time a mountain of considerable elevation, but a hill consisting of tuff alone, as appears to be the case with a large part at least of Rocca Monfina, could only have attained its present height, which is at least 2000 feet above the sea, in consequence of some elevatory movement subsequent to its ejection; and if this be admitted, we have before us in the central trachytic rock of Monte della Croce, an agent calculated to cause such an upheavement, and itself hardly to be accounted for without such a supposition.

A few miles west of Mola di Gaieta lie the Ponza Islands, four of which, namely Ponza, Palmarola, Ventotienne, and San Stefano, appear to be entirely volcanic, the fifth (Zannone) in part neptunian. No tradition exists of their having been in activity, nor was Dolomieu, who first described them, able to discover in them any traces of a crater. The most detailed account published of them in recent times is that by Mr. Poulett Scrope, now contained in the Transactions of the Geological Society for 1824.

With the exception of Zannone, all this group is composed of rocks more or less of a felspathic character, and in general referable to one or other of the members of the trachytic series. Of these rocks, beautiful sections are presented above the line of coast, where their internal structure is completely laid open.

The largest of these islands, that of Ponza, is long and very narrow, and is eroded by the sea into deep concavities. Harder masses left along its shores in the sea adjoining show that it once was broader than it is at present, and protruding ledges of rock even mark its former connexion with Zannone and with the little islet called La Gabbia.

Prismatic trachyte, disposed in zones of various colours, frequently waved and contorted like the stripes of certain varieties of marbled paper, and interspersed with cells, the

longer axis of which is in the direction of the laminæ of the stone, appears to form the skeleton of the island. It is constantly accompanied by, and alternates with, a semi-vitreous trachytic conglomerate, formed of minute pulverulent matter inclosing fragments of trachyte.

The prismatic trachyte seems to have been forcibly injected through the conglomerate, and wherever it touches the latter, its earthy base is converted into a pitchstone porphyry; sometimes it becomes a pearlstone, and at other times it incloses small *nuclei* of true obsidian.

These rocks are connected with a siliceous trachyte, resembling in appearance the siliceous buhrstone of Paris, and probably belonging to the molar porphyry of Beudant. It consists of a white, earthy, and friable substance, traversed by irregular concretions possessing a compact texture, ash-grey colour, and flinty lustre. It is accompanied by breccias and conglomerates equally siliceous.

Abich appears to refer all these descriptions of rock to the trachyte-porphyry of Beudant passing into various modifications of pearlstone and obsidian. Like Scrope, he regards it as protruded in dykes through the pumiceous tuff, by the removal of which the former stand out in long rows like colossal walls. Hence the peculiar figure of these islands, and the steep and generally perpendicular precipices which they present towards the sea.

Resting on the semi-vitreous trachyte, and forming the base of the highest point in the island, the Montagne della Guardia, is a rock 300 feet thick, which Mr. Scrope distinguishes from trachyte, as containing, in addition to the felspar which constitutes the predominant ingredient, a small percentage of augite, hornblende or mica, and which he denominates *greystone*. It is however stated to resemble the rock of Mount Olibano, hereafter to be described*, which Abich calls trachyte-dolerite.

The structure of Palmarola nearly resembles that of the larger island Ponza contiguous, except that the siliceous trachyte does not occur. The rock composing it, Abich says, may be regarded as consisting of 50 per cent. of glassy felspar, 25 of albite, and 25 of silica, or of a solution of a neutral

* See the 12th Chapter.

silicate of alumina and of alkali in silicic acid; and with this the rock of Ponza corresponds.

The constitution of Zannone is very peculiar, two-thirds being composed of trachyte, the rest of limestone. The former corresponds with the molar porphyry of Ponza, and presents all the external features of a buhrstone. It might be mistaken from its white colour for a cavernous freshwater limestone or travertin, and is composed, according to Abich, of silica 28·40, hydrate of iron 1·33, orthoclase 34·34, and glassy felspar 35·83. Hence, whilst the slaty and glassy trachyte (trachyte-porphyry) of the Ponza islands abounds in soda, the siliceous kind (or molar porphyry) is richer in potass. The limestone, which constitutes the remaining third of the island, is described by Brocchi as transition, corresponding with that of the Monte Circello on the opposite coast of Italy. Near the line of contact with the trachyte it has become dolomitic.

The next island, Ventotienne, consists wholly of pumiceous conglomerate or tufa, interstratified with beds of lapilli, and resting upon a massive bed of what Mr. Scrope denominates *greystone*.

The remaining island, San Stefano, resembles in structure Ventotienne, consisting of a rough mass of greystone surmounted by loose tufa.

Thus the Ponza group may be considered as composed of two classes of volcanic products, separated one from the other by masses of tuff or pumiceous conglomerate.

The first of these classes will comprehend two varieties of trachyte, namely the trachytic porphyry and the molar porphyry of Beudant, the former of which also associated with pearlstone and obsidian.

The latter class consists of the *greystone* of Scrope, or the *trachyte-dolerite* of Abich, and exhibits a still further step in the volcanic process, from the presence in it of augite and certain other minerals in lieu of a portion of the redundant silica.

CHAPTER XI.

VOLCANOS OF SOUTHERN ITALY (*Continued*).

Mount Vultur described—antiquity of its eruptions—peculiar constitution of its lava—configuration of the country when it was in an active state.—Lago di Ansanto—referred to by Virgil—mephitic vapours given out by it—rocks in which they occur—position of the lake with reference to the two volcanos of Vultur and Vesuvius.

In the province of Basilicata, a part of Apulia, and on the eastern flank of the Apennine chain, rises near the city of Melfi a lofty isolated hill, the Mount Vultur*, which Horace has celebrated as the scene of his early poetical adventures†.

This mountain, both from its conical form and the nature of the rocks composing it, is at once recognised as volcanic. Its remoteness from the ordinary routes of travellers, and the insecurity of the roads in that part of Italy, have caused it to be very little explored; but since the publication of the former edition of this work, it has been visited by myself‡, and at a still later period by Abich.

I found the mountain composed principally of volcanic tuff, some beds of which were very compact, whilst others were loose and friable, consisting chiefly of pumice like those about Pompeii. On its northern flank, about half-way from the summit, is a great circular expansion, surrounded by an amphitheatre of rocks on all sides except the lower by which we had ascended, some of which rise more than a thousand feet above the average margin of the cavity. It evidently was

* See Plate II., entitled 'Town and Castle of Melfi with Mount Vultur beyond, seen from the N.E.'

† Me fabulosæ, Vulture in Appulo,
Altricis extra limen Apuliæ,
Ludo fatigatumque somno,
Fronde novâ puerum palumbes
Texere. Carm. lib. iii. ode 4.

‡ See 'Narrative of an Excursion to the Lake Amsanctus and to Mount Vultur in Apulia,' Transactions of the Ashmolean Society, vol. i.

once the crater of the volcano *, and contained within it two minor depressions, in both which were lakes communicating by a narrow outlet one with the other, and discharging their superfluous waters by means of a little rivulet which runs from the lower and more southern of the two lakes.

It is stated, that at times volumes of sulphuretted hydrogen or of some other inflammable gas are given off from this lower lake, and that jets of water have been suddenly thrown up to the height of fifteen feet above its surface. Near it I discovered a cold spring called the Aqua Santa, without any particular taste, but possessing some reputed medicinal virtues, which gave out bubbles of air, consisting, according to my analysis, chiefly of carbonic acid, but with a small residuary quantity, containing nine-tenths nitrogen to one-tenth oxygen. Waters containing carbonic acid and sulphuretted hydrogen are likewise found to the east of Mount Vultur at Rendina, and on the west near Atella.

These circumstances may tend to show that the volcanic action is not entirely spent, but manifests itself at intervals by the evolution of gas.

Nevertheless there is not the slightest reason for supposing that this volcano was in activity within the historical period; on the contrary, during the times of ancient Rome its condition would appear to have been but little different from that which at present belongs to it.

Horace would hardly have selected it as the spot, where the doves are represented as covering him over in the days of his childhood with fresh leaves, had not the forests existed then in their present luxuriance; and if the mountain had appeared to the poet under that arid and forbidding aspect, which belongs to all volcanos that have been but a short time extinguished, he would have introduced some mention of such a circumstance, when he alludes to the peculiar features of the neighbouring places,—the "excelsæ nidum Acherontiæ," the "saltus Bantinos," the "arvum pingue humilis Ferenti."

Lucan too speaks of the "arva Vulturis," without any allusion to the harsh and sterile appearance which belongs to a mass of recently ejected lava.

Indeed, not a single stream of lava was observable, either

* See Plate IV., entitled 'Crater of Mount Vultur from the S.W.'

on the road we took from Melfi to reach the crater, or on our return over the western edge of the crater to that city. If any such there be, they were concealed by a thick bed of black unctuous soil, resulting from the mixture of volcanic ashes with the clay, which proceeded from the decomposition of harder materials.

The extent to which this has taken place—the rare occurrence, in a mountain which once was the theatre of such extensive volcanic operations, of loose blocks—and the entire disappearance of the streams of lava—would alone imply the long interval of time that had elapsed since the eruption that occasioned them; but another proof of the same fact was afforded me, in the existence of a deep and wide valley which we crossed on our way, extending from the bottom of the mountain nearly up to the crater, completely covered with vegetation, and with its superficial strata reduced to the condition of a rich and slippery loam.

In the few specimens of volcanic rock met with on our road, either in detached blocks, or composing beds of loose materials which the soil had not completely concealed from our view, there was a general uniformity of character.

They consisted of a dark and generally compact, though sometimes cellular stone, which was made up of an intimate union of minute crystals of augite imbedded in a felspathic base. There were also dispersed through the matrix crystals of a dark green colour, which from a comparison with others subsequently found, I conclude to consist of *hauyne.*

These masses may either have been detached from a stream of lava which formerly had been thrown out, or may have been ejected separately.

If the former were the case, what an idea of antiquity does the complete concealment by vegetation of these streams convey to the mind, when we recollect the ages required to cover even with lichen those of Etna or Vesuvius! Yet the whole of these eruptions was posterior to the formation of the tuff constituting the base of the mountain, which is of various degrees of compactness, containing comminuted masses of pumice imbedded, which alternates with beds of loose pumice, without any cementing material.

The town of Melfi stands on an isolated neck of land,

separated from Mount Vultur by a valley and stream of water*.

The rock is based upon volcanic tuff like that of Vultur, the beds of which dip from that mountain. The summit of the hill however consists of a thick bed of compact lava resting on tuff, and presenting a precipitous escarpment, as well as an imperfect columnar structure, towards the north-east. Here the best specimens of hauyne are to be met with, in a bed of loose volcanic stones underlying the town above noticed.

When the crystals are capable of being detached from the matrix, they are generally found to possess the dodecahedral form, which in other localities is seen so imperfectly, well-defined; and they are characterized moreover by gelatinizing with nitric acid, and by fusing into a blue glass with borax.

The blue kind found at Andernach and in the Campagna di Roma is less common here than the dark green variety, and owing to some external decomposition, the former is white superficially, and presents its natural colour only when fractured. It is accompanied with leucite, with augite, with hornblende, and according to Brocchi with pseudo-nepheline, and melilite. In the compact lava-bed which overlies the congeries of ejected masses described, I also perceived concretions very much resembling the pearlstone of Hungary.

Mount Vultur has lately been measured by Abich, who finds its highest point 2468 Paris feet above Melfi, and 4156 feet above the sea. Accordingly at Frigento, a place which is nearly equidistant from it and Vesuvius, the summit of Vultur appeared more conspicuously than that of Somma over the Apennine ridge. It is about twenty miles in circumference, and is made up of an aggregate of several hills, having steep escarpments towards the interior, whilst their external slopes are more gentle.

It has been conjectured† that the eruptions of this mountain took place at a time when the physical structure of the country was different from what it is at present, and the low land between Melfi and the Adriatic constituted a sort of

* See Plate III., entitled 'View of the Town and Castle of Melfi.'

† Cagnazzo, Congettura di un antico sbocco dell'Adriatico. Napoli, 1807, as quoted in Romanelli's Topografia del Regno di Napoli.

gulf, extending from Taranto upwards, the waters of which washed the foot of this volcano.

Not having seen the work referred to, I am unable to state in what degree this hypothesis is borne out by fact, and shall only remark that it seems favoured by the direction of the Apennines as laid down in common maps*, where they are represented as dividing about Melfi into two branches, one of which takes the direction of Bari to the east, the other that of Calabria to the south, thus inclosing the greater part of the province of Basilicata in a kind of basin. What this intermediate tract of country may consist of, I have not been able to ascertain; but should it be such as to confirm such a conjecture as to an extension of the gulf at one period in the direction contended for, we may derive from the present extinct condition of Mount Vultur, an additional proof of the theory which I shall propose in another part of this work, with respect to the necessity of the access of the sea, or at least of large bodies of water, to feed the fires of every volcano. At present the distance of Mount Vultur from the Adriatic cannot be less than thirty-five miles, whilst from Naples it is nearly twice as remote.

Midway between the two volcanos of Mount Vultur and Vesuvius, and in a direct line intersecting each, is the Lago di Ansanto †, in which name the classical reader will directly recognise the lake and valley of Amsanctus alluded to by Virgil, into which the fury Alecto plunges, after having excited discord between Turnus and Æneas:—

> Est locus, Italiæ medio sub montibus altis,
> Nobilis, et famâ multis memoratus in oris,
> Amsancti valles: densis hunc frondibus atrum
> Urget utrinque latus nemoris, medioque fragosus
> Dat sonitum saxis, et torto vertice torrens:
> Hic specus horrendum, sævi spiracula Ditis
> Monstratur: ruptoque ingens Acheronte vorago
> Pestiferas aperit fauces; quîs condita Erinnys,
> Invisum numen, terras cœlumque levabat.
>
> ÆNEIS, lib. vii. l. 563.

* See the excellent map attached to Dr. Cramer's useful 'Description of Ancient Italy.' Oxford, 1826.

† See the Map of a portion of the kingdom of Naples, in which the

Some indeed have suggested that Virgil alluded to certain sulphureous ponds that occur near Rieti, above the famous falls of Terni, where the immense accumulation of travertine proves that the extrication of carbonic acid, and probably of other gases usually accompanying it, has been taking place on an enormous scale; but the locality seems to be fixed by a passage in Cicero, who expressly says, that the Lake Amsanctus lies in the country of the Hirpini:—"Quid enim? non videmus quam sint varia terrarum genera? Ex quibus, et mortifera quædam pars est, ut et Amsancti in Hirpinis, et in Asia Plutonia." A passage in Pliny might also be quoted to the same purpose, but the description which Virgil gives is so applicable to the spot, that I conceive no doubt can remain as to its identification.

Thus Ansanto stands "Italiæ medio" (midway between the Adriatic and Mediterranean); "sub montibus altis," (having in its immediate neighbourhood the hills of Frigento, Villa Maina, &c., and at a still greater distance the mountainous heights of Monte Vergine, and other of the loftiest points in the chain); it is situated in a little valley, which till lately was flanked on either side by a thick wood,—

> densis hunc frondibus atrum
> Urget utrinque latus nemoris,

for it was only in the time of Murat that the wood on the right hand was cut down; whilst a small mountain torrent flows down the valley and supplies the lake,—

> medioque fragosus
> Dat sonitum saxis, et torto vertice torrens.

Here from the pool, which occupies a particular spot where the valley is somewhat wider than elsewhere, issues an enormous quantity of noxious gas, whilst the same proceeds copiously from a cavity in an adjacent rock, so that the latter part of the poet's description is exactly verified:—

> Hic specus horrendum, sævi spiracula Ditis
> Monstratur; ruptoque ingens Acheronte vorago
> Pestiferas aperit fauces.

Lastly, they point out on an adjoining eminence some vestiges of the neighbouring temple to the goddess Mephitis; and Romanelli notices an inscription found on the road from Ariano to Montecalvo, which makes mention of a votive offering presented to the goddess by a Roman lady,—

Paccia Quintilla Mefiti votum solvit.

---

dark band shows the direction of the volcanic forces extending across the peninsula from Ischia through Vesuvius, skirting the side of Lake Amsanctus, and terminating in Mount Vultur.

I visited this spot in the year 1834, on my way to Mount Vultur, and having descended the hill on which Frigento stands, shortly came upon a small pool of water, which, like the larger one to which attention has chiefly been directed, emits a quantity of gas. This I collected in the usual manner, by inverting a jar full of water over the spot on the surface of the pool from which the bubbles issued, and on my return to Frigento in the evening submitted it to chemical examination, which proved it to consist partly of carbonic acid and partly of sulphuretted hydrogen. After the removal of these two gases however, there was a small residuary quantity of air, which contained about 16 per cent. of oxygen and 84 of nitrogen.

We next reached the narrow valley, or rather watercourse, in which the larger pool of Amsanctus is situated. Nearly two miles below it is a warm spring which disengages carbonic acid and sulphuretted hydrogen gases, and which in the lapse of ages has produced on either side of the water a thick deposit of travertine.

A little beyond us towards the south was the town of Villa Maina, standing on an eminence, which I am induced to notice from a circumstance, stated to me by a resident gentleman who was of the party respecting it, which seems worthy of notice.

He assured me, that the health of the inhabitants had appeared to suffer materially, since the cutting down of the wood which lay betwixt them and the mephitic lake; that they were sensible of the odour proceeding from it when the wind blew from that quarter, which was not the case before; and that they attributed the insalubrity of the situation to that circumstance. My informant further assured me that the inhabitants of Villa Maina are noted for the sallowness of their complexions, and that the disease to which they are chiefly subject is an affection of the liver *.

* Fanciful as it may appear to connect any disorder of the animal functions with the minute quantity of a deleterious gas, which can be so wafted to a distance so great as four miles from the place of its emission, I am not disposed altogether to pronounce its influence impossible; for without being a convert to the doctrine of homœopathy in the extent to which it is often carried, I can conceive that the long-continued action of a very minute

The quantity of mephitic vapour which proceeded from that quarter was such, as to oblige us (the wind being in the north) to take a circuit towards the east in order not to meet the noxious blast, instances not unfrequently occurring of animals, and even men, who had imprudently ascended the ravine, being suffocated by a sudden gust of air wafted from the lake.

This is the origin of the fable of the Vado Mortale, a particular spot in the course of the rivulet that flows from the lake, which, it is said, cannot be forded without death, and has been described as exhibiting on its borders an accumulation of the whitened bones of the various animals that had perished there, destined to continue for ever on the spot where they fell, because no living creature can approach to take them away without adding to their number.

The wonders of the Lake Amsanctus are sufficiently striking without any such exaggeration; no bones existed in the valley at the time I visited it, except a few belonging to some birds, which in crossing the valley had been arrested on their wing by the noxious effluvia, as was the case at the Lake Avernus of old; neither even close to the lake, where the evolution of gas is most abundant, is there any point at all times unapproachable, for we ourselves were able to reach its edge on the side from whence the wind was blowing.

I have already stated that the pool itself stands in a part of the ravine which is widened out considerably, contracting again to its original dimensions below. It has been stated as being about twenty paces in its smallest diameter and thirty in its largest, which I conceive to be near the truth; and its depth is said to vary from six to seven feet. From the quan-

quantity of a noxious ingredient may sensibly influence the system, whilst an infinitely larger dose applied during a short space of time may be thrown off without inconvenience, in consequence of the resistance which the vital principle opposes to its introduction, or as our predecessors in the medical art preferred to denominate it, the *vis medicatrix naturæ*. Thus it is at least not absurd to suppose, that an individual who had exposed himself for some hours to these vapours within the crater of Vesuvius, in the most concentrated state in which they can be endured without subsequent injury, might be affected by inhaling during many years a very minute portion of the same, wafted from the Lake Amsanctus whenever the winds set in that direction.

tity of gas which is continually escaping, it appears to be throughout in a state of violent ebullition, but its temperature little, if at all, exceeded that of the surrounding atmosphere.

The colour of the water is dark and muddy from the quantity of sediment projected towards the surface, owing to the constant agitation into which the pool is thrown by the gas that rises up through it; its taste strongly bespeaks the presence of alum, which is said to render it efficacious in the cure of certain diseases of cattle.

One of the guides who approached its edge filled a bottle with the water; but to have collected the gas itself would have been a perilous attempt. I can only infer therefore that it resembles that which issued in smaller quantity from a more inconsiderable pool within a hundred yards of the spot, and which consisted mainly of carbonic acid gas. The smell however plainly indicated that sulphuretted hydrogen was likewise emitted at the former vent, and the consequences of the long-continued action of this gas upon the constituents of the contiguous rock was not the least interesting and instructive phænomenon presented in this locality.

The rock itself, everywhere in the vicinity of the Lago di Ansanto, is the common blue fissile limestone interstratified with beds of grit, which had accompanied us from Avellino. There is nothing that reminds us of volcanic action except about the lake, where those products which usually are found in solfataras and in other spots exposed to the action of sulphureous vapours abound.

Thus the rock immediately round the pool consists of a pulverulent earthy substance, derived from the conversion of the carbonate into sulphate of lime, and the production of alum from the union of the same acid with alumina; sulphur derived from the sulphuretted hydrogen gas also impregnates it in sufficient quantity to be worth collecting; and in some places the colour and smell indicate the presence of petroleum, disengaged along with the sulphur from the depths below.

Moreover, as a proof that this action is not altogether local, and that it is capable of producing effects on a scale commensurate to those exhibited in several of our rock formations, a bed of gypsum nowise different from those of many tertiary

deposits may be noticed as occurring at a short distance, resting upon the Apennine limestone.

It is interesting to remark, that the position of this spot is almost exactly intermediate between the active volcano of Vesuvius and the extinct one of Mount Vultur, and that a straight line drawn from the one to the other, and which might likewise be extended on to the volcanic island of Ischia, would pass within a mile or two of this mephitic lake *.

From the neighbouring eminence on which Frigento is situated, the summits of both mountains were alike visible; and it was stated to me on the spot, that when Vesuvius was in a state of activity, an unusual quantity of gas was disengaged from Amsanctus. Hence it seems probable that the same elements of volcanic activity exist underneath the earth all across the peninsula, although these elements may be called into more intense action on either side of the Apennine chain, by the proximity of sea water, or by some other circumstances which do not occur in the central portion of the chain.

* See the point at which the Lake of Amsanctus stands with reference to these other mountains, marked on the 'Map of a portion of the kingdom of Naples' appended to this volume.

CHAPTER XII.

SOUTHERN ITALY (*Continued*).

Neighbourhood of Naples—Phlegrean Fields—Tuff or Puzzolana—its height and extent—Grotto of Posilippo—Lake Agnano—Grotto del Cane—Lake Avernus—Monte Barbara—Astroni—other craters in the tuff.—Trachyte—Piperno—proofs of elevation—Temple of Puzzuoli—Monte Nuovo—Solfatara—action of the gases emitted upon this rock—lava-stream given out from it.—Vesuvius—its condition prior to the Christian æra—first recorded eruption—history of its eruptions up to 1845—products of its eruptions—its lavas—distinction between those of Somma and Vesuvius.—Monte Somma—how formed—ejected masses—list of minerals, &c.—gaseous products evolved.

I NEXT proceed to the third and most important system of volcanos in the South of Italy, which is exhibited in the immediate neighbourhood of Naples itself.

The fundamental rock throughout the district, so far as our present knowledge extends, appears to be the Apennine limestone, which some geologists refer to the Jura, and others to the Chalk formation, but which seems to be identified with the latter by the presence in it of Hippurites and of certain species of fish (*Pycnodus rhombus*, Agassiz).

This, though covered by alluvial or supracretaceous beds in many places near the coast of the Mediterranean, rises into the high cliffs of Sorrento and of the contiguous island of Capri, and is seen again bounding the Terra di Lavoro, near Capua, at Caserta, &c.

It is remarkable that this rock appears to present no indications of igneous action; at least I have never observed myself, nor have I seen described by others, any trap-dykes penetrating its substance, or interfering with its stratification. Thus there was a time, as it would seem, in the history of our planet, when the neighbourhood of Naples was exempt from the influence of those igneous operations which are now so prevalent throughout every part of it.

Not only indeed was the Apennine limestone deposited,

but the whole of its surface was in great measure moulded into its present configuration, before any products of volcanic action began to be emitted.

The oldest of these is a tuff of a nature similar to that which has been so often before described, and yet this is posterior to many of the limestone valleys, as beds of it are seen filling up their hollows, not only near Naples itself, but in the valley of Maddeloni near Caserta; near Sorrento, insinuating itself into the narrow gorges existing in the Apennine limestone; and even rising so high as Pagani, a village situated in a hollow not far from the summit of the Sorrentine hills.

Thick beds of tuff also extend nearly to Salerno through the valley of Nocera, about Ponta, and several miles east of Avellino, spreading to a considerable distance up the slopes of the Apennines.

The basis of this tuff is for the most part of a straw-yellow colour, dull and hard to the feel, with an earthy fracture, and commonly a loose degree of consistency. It seems to be made up of comminuted portions of pumice formed into a kind of paste, in which are imbedded fragments of pumice, obsidian, trachyte, and many other varieties of compact as well as of cellular lava, the softer kinds often rounded, the harder mostly angular. It is regularly stratified, and alternates with beds of loose uncemented pumice, of ferruginous sand, of loam, and in one or two cases of calc-sinter, in which fragments of limestone are impacted.

As I did not myself succeed in detecting any kind of rock, except of a volcanic nature, imbedded in the tuff, and as the new road constructed round the promontory of Nisida gives us now a good opportunity of examining it, I apprehend such specimens are not common.

Sir W. Hamilton however long ago detected shells in this rock, and the fact has been confirmed by more recent observations, for Monticelli enumerates *ostreæ*, *cardia* and *pectens* in the tuff of Puzzuoli; Professor Pilla a large *ostrea* and a large *pectunculus* at the castle of St. Elmo overlooking Naples; and Mr. Scrope, *ostreæ*, *cardia*, *buccina*, and *patellæ* in the promontory of Posilippo—shells, be it observed, existing for the most part at present in the Mediterranean.

I observed at Capo di Monte, just above the city of Naples.

veins of a harder variety of tuff penetrating the rock. The matter composing these veins in their most compact form approaches nearly to porcelain jasper, is splintery, and has a conchoidal fracture. In these cases its surface is smooth and its texture uniform, but when it is traced on, we discover in it a fragmentary structure, bits of obsidian, porphyry, pumice, and lapilli of various sizes and kinds being imbedded in the same paste. In other instances little veins of the same fragmentary variety of rock pass through the substance of the compact and uniform kind. The harder varieties of tuff here described as veins contain specks of mica disseminated through them. The bed of tuff underneath it is of a very loose consistence, and is composed principally of a congeries of grains of sand and lapilli.

We are naturally disposed to attribute the origin of this variety of tuff to fissures existing in the bed, which were subsequently filled up by water holding suspended the finer particles of the same material, the only question being, whether the hardness of the resulting vein, and its occasional passage into the surrounding parts of the bed, imply the subsequent operation of heat upon its materials.

The volcanic tufa spreads over the whole region comprehended between the Apennines and the Mediterranean, within the limits embraced by the Bay of Naples, beginning a little north of Cumæ, and extending south to that arm of the Apennines which forms the mountain-chain of Sorrento.

Its height in many places near Naples is very considerable —the hill of the Camalduli, 1643 feet above the sea, and the most elevated point next to Vesuvius in the whole country, being composed of it; and to the west of Naples it forms a sort of wall so lofty and abrupt, that the former inhabitants of the country apparently found it easier to avail themselves of the soft and friable nature of the stone, and to cut through, than to make a road over it.

This is the origin of the celebrated Grotto of Posilippo, a cavern 363 toises, or 2178 feet in length, 50 feet in height, and 18 in breadth, which strikes every stranger with surprise from the mass of rock cut through, until he reflects at the ease with which a stone of such a description admits of being hollowed out.

This immense mass of Puzzolana forms some considerable hills round Naples, many of which, as the Monte Barbaro, Astroni and others, have very regular craters, but do not appear to have thrown out any currents of lava.

The Lake Agnano has every appearance of occupying the original site of a crater, as the strata, whose edges are visible in its interior, instead of having a corresponding dip on the opposite sides of the cavity, as is commonly the case with valleys formed by denudation, seem on the contrary to slope in all directions away from the crater, just as would happen if the strata had been thrown up by a force acting from below.

The volcanic action here, as in many other places round Naples, appears hardly extinct, for there are exhalations of warm vapour impregnated with sulphuretted hydrogen constantly rising near the lake, which are much esteemed in various complaints.

I tried with success the curious experiment of lighting a piece of paper in contact with one of the crevices from which the vapour issues, the immediate effect of which is to cause a more abundant evolution of gas from this point, owing, as I supposed, to a local rarefaction of the air caused by the heat applied, which produced a partial vacuum, and thus determined to this point more of the elastic vapour from the interior of the cavern.

M. Piria however has proposed a different explanation*, regarding it as a catalytic action, similar to that which spongy platinum exerts upon hydrogen gas. He finds that charcoal and many other substances in a state of incandescence, brought near a volume of sulphuretted hydrogen gas, cause the production of sulphurous acid and water, and he infers that this is not simply the effect of heat, because glass and some other bodies heated as strongly do not produce the same. Hence when a piece of lighted paper is brought near a crevice from which sulphuretted hydrogen is slowly escaping, it occasions a decomposition of the gas, and an evolution of steam and sulphurous acid from that point. Fragments of lava act upon the gas just as carbon does, and hence heated lava may produce fumaroles by decomposing the gas just where it escapes from the earth.

The celebrated Grotto del Cane, situated on its borders, is constantly giving out volumes of carbonic acid gas, containing

* See Comptes Rendus, 1840, tom. ii. p. 352.

in combination much aqueous vapour, which is condensed by the coldness of the external air, thus proving the more exalted temperature of the spot from whence it proceeded.

The mouth of the cavern being somewhat more elevated than its interior, a stratum of carbonic acid goes on constantly accumulating at bottom, but upon rising above the level of its mouth flows like so much water over the brim. Hence the upper part of the cavern is free from any noxious vapour, but the air of that below is so fully impregnated, that it proves speedily fatal to any animal that is immersed in it, as is shown to all strangers by the well-known experiment with the dog.

The sensation I experienced, on stooping my head for a moment to the bottom, resembled that of which we are sometimes sensible on drinking a large glass of soda-water in a state of brisk effervescence. The cause in both instances is plainly the same.

The quantity of carbonic acid present in the cavern at various heights was shown, by immersing in it various combustibles in a state of inflammation. I found that phosphorus would continue lighted at about two feet from the bottom*, whilst a sulphur-match went out a few inches above, and a wax-taper at a still higher level.

It was impossible to fire a pistol at the bottom of the cavern, for though gunpowder may be exploded even in carbonic acid by the application of a heat sufficient to decompose the nitre, and consequently to envelope the mass in an atmosphere of oxygen gas, yet the mere influence of a spark from steel produces too slight an augmentation of temperature for this purpose.

It is probable that the Lake Avernus may likewise have been the crater of a volcano, and afterwards a channel for the escape of gases generated by the same cause, a supposition which will account for the noxious properties attributed to it by the ancients†:—

* Forsyth has erroneously stated that though torches of gunpowder lose their inflammability there, yet phosphorus resists the carbonic acid.

† When we consider the considerable specific gravity of sulphuretted hydrogen gas, it is very reasonable to suppose that the thick woods which in former times surrounded the Lake Avernus would favour materially the accumulation of this noxious vapour. The surface of the lake, screened from the access of the winds in every quarter, must have been covered with a thick stratum of unrespirable gas which would be very slowly dissipated. If carbonic acid were present, the same thing would take place with this in even a much greater degree than with the former. But when the woods were cut down, as we are told was done by Agrippa, the air of the lake

Quam super haud ullæ poterant impune volantes
Tendere iter pennis: talis sese halitus atris
Faucibus effundens supera ad convexa ferebat:
Unde locum Græci dixerunt nomine Aornon.

At present no such exhalations are given out, and birds seem to resort to it as much as to any lake near Naples.

The Lakes of Agnano and Avernus then are examples of craters converted into lakes, and may be compared with those of the Eifel district noticed in the fourth chapter.

The circumstances indeed under which the volcanic action was manifested in both these countries seem to have borne to each other a considerable analogy, as what we observe is not a single lofty conical mountain, like Ætna or Vesuvius, from which streams of lava have successively been derived, but either a series of circular depressions in the midst of the Puzzolana, as those of Avernus and Agnano, or certain comparatively low hills with craters rising out of them, which in most instances appear to have given vent solely to exhalations of gaseous matters, or to ejections of scoriæ.

Of these the Monte Barbaro* is probably the most elevated; it has a crater on its summit, one side of which is broken away, and its extreme antiquity is manifested by the circumstance of its surface being covered with verdure. A single

would become continually intermixed with the surrounding atmosphere, so that, unless a pretty rapid disengagement of gas took place, the noxious qualities would cease. This coincides with the accounts of Strabo, Silius Italicus, and other classical writers.

* This mountain is frequently noticed in ancient writers under the name of Gaurus, and was famous for its vineyards. The following elegant lines by Aurelius Symmachus, one of the later Latin poets, allude to this, as well as to the heat of the water near its foot:—

Ubi corniger Lyæus
Operit superna Gauri;
Vulcanus æstuosis
Media incoquit cavernis;
Tenet ima pisce multo
Thetis, et vagæ sorores:
Calet unda, friget Æthra;
Simul innatat choreis
Amathusias renidens,
Salis arbitra, et vaporis,
Flos siderum, Dione.

farm-house indeed is seen in the interior of the crater, in the most solitary situation probably that could have been chosen within so short a distance of a great capital.

Another remarkable crater is that of Astroni, the perfect condition of which has caused it to be selected by the King of Naples as a preserve for his wild boar and other animals destined for the chase; it is a circular cavity, nearly a mile in diameter, the walls of which are formed of a congeries of scoriæ, pumice, and other ejected materials, in regular strata dipping away in all directions from the centre, which, as at Rocca Monfina, is occupied by a boss of trachyte protruding above the level of the cavity to the height of 200 feet.

Hillock of Trachyte in the centre of the Crater of Elevation of Astroni.

If we believe Breislac, the number of craters of which indications exist in the neighbourhood of Naples amount to no less than twenty-seven; but after the specimen we have already had of the readiness with which that geologist has imagined craters to exist on the very site of ancient Rome, where recent observers altogether deny the existence of any, we naturally feel suspicious of his authority on such a subject, especially as he does not appear to have applied the only *test* by which hollows that establish the existence of craters can be clearly distinguished from those derived from other causes, —I mean the direction of the strata composing their walls.

These, it is evident, ought in the case of a valley of denudation to possess a similar inclination and dip on the opposite sides; whereas in a crater they will diverge in all directions from the original centre of the cavity.

In the following sketches A represents a valley originally formed by water, B one resulting from a crater partially destroyed:—

Valley formed out of a Crater. *Valley formed by Denudation.*

It may also be remarked, that if we only grant the Puzzolana to have been subjected to the action of water since its deposition, the existence of many hollows and other irregularities of surface, which Breislac regards as the remains of craters, is readily explained; for it is evident that a rock of so soft and yielding a texture ought, of all others, to exhibit the most decided evidences of what has been called diluvial action.

Nevertheless there seems no doubt that the promontory of Cape Misenum formed a portion of the margin of a crater, whilst the rock facing it, which is interposed between the Mare Morto and the Lake of Fusaro, constitutes a portion of its opposite lip, the Mare Morto itself occupying what was once the interior of the crater.

The island of Nisida also appears to have comprised within itself a volcanic crater, one side of which, forming the entrance to the Porto Pavone, is broken away; the basin-shaped cavity in which the village of Pianura is situated seems to have been a third; and others have been pointed out by more recent writers.

It is unnecessary however for our present purpose to go through the entire list, as even if we limit the craters that existed in the Phlegrean fields to those of which present appearances leave no doubt, their number will be sufficient to give us a frightful picture of the condition of the country at an early period of history, and serve to account for the fables of the poets, who imagined the entrance to the infernal shades to lie among these recesses.

It was not then, as at present, a single mountain which sent forth flames and melted matters at certain intervals, and secured a comparative immunity to the rest of the district; but there would appear to have been a constant exhalation

of noxious vapours from a variety of orifices, attended with earthquakes, and other phænomena which bespeak the operation of volcanic agency over a widely-extended surface.

If then the early settlers in Sicily were so alarmed at the eruptions of Mount Ætna as to fly to some other part of the island, and if in modern times, among the Canaries, the inhabitants of Lancerote were compelled to migrate on account of the ravages made upon their possessions during a succession of years by subterranean fire, it is not unnatural, that the picture which Homer had received of the Phlegrean fields should have been so terrific, as to have led him to describe them* as placed at the utmost limits of the habitable world, unenlightened either by the rising or setting sun, with groves consecrated to Proserpine, rivers with streams of fire, and enveloped in an eternal gloom. These ideas would be confirmed, if we imagine that the Cimmerians, who first peopled the country, lived in those caverns and hollows of the rock which now exist, and were thus by the very nature of their habitations shut out from the light of day†.

Such a picture indeed accords very little with the ideas suggested by the luxuriance of modern Campania; but it must be recollected that at the time when Homer wrote, that luxuriance had not yet been developed by cultivation, and

* Odyssey, K. Λ.

† I have noticed in my memoir on Sicily (Edinb. Journal) the existence of artificial caverns, which we hardly know whether to consider as the dwellings or burial-places of the early inhabitants. Though wretched abodes, they would at least be preferable to those from which I have myself seen the Cyganis of Hungary creep out, which were literally holes in the ground, in which they burrow like the Troglodytes of old. Capt. Lyon has described similar residences in Northern Africa (see his Travels, p. 25). But there can be no doubt, from the number of caverns noticed by travellers in the East (see particularly Buckingham's Travels in Palestine, p. 113), as well as from history, sacred and profane, that the practice of hollowing out the rocks of the country for habitations in many instances long superseded the use of them for erecting regular houses. No rock however affords facilities for this practice equal to the tuff of volcanos, and accordingly, wherever this occurs, we find even at this day that dwelling-places are excavated in it. Such is the case in Ischia, in Auvergne, and in the Vivarais. That the Puzzolana of Naples therefore should be hollowed out for this purpose is no more than we might reasonably expect.

that whilst the recent occurrence of the eruptions may have devoted many parts to a temporary sterility, others would be overshadowed with thick and gloomy forests.

We have already alluded to the trachytic blocks which are found amongst the materials of the tufaceous deposit, and must therefore admit that trachyte was formed at an antecedent period. Nevertheless there seems good reason for supposing that this latter rock has been heaved up in a pasty condition here, as at the Puy de Dôme in Auvergne, in more than one spot included within the district we are considering, since the deposition of the tuff.

At Pianura, a circular plain at the foot of the northern escarpment of the hill of Camalduli, we observe a singular description of rock called *Piperno*, extensively quarried for the steps of houses, sills of windows, and other building purposes at Naples. It may be described as a sort of volcanic breccia, bearing the same relation to the ordinary tuff, which Sienna marble does to an ordinary puddingstone, containing the same fragments of volcanic matter as the latter, but with the imbedded fragments so blended with the cementing material as to appear like a part of the same.

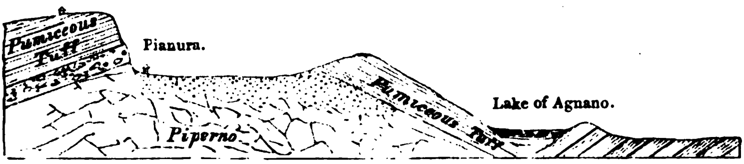
These fragments, which are sometimes without, but more commonly with cells, are often compressed and lengthened out in a horizontal direction, and are imbedded in a whitish paste similar to ordinary tuff, but more compact.

The impression which the appearance of Piperno created in my mind when I visited the spot in 1834, was that of a bed of ordinary tuff, which, after it was originally deposited, had been subjected to the action of heat under pressure, and in this manner had undergone a kind of partial fusion.

Dufrenoy however considers it a variety of trachyte, consisting of fragments of this rock agglutinated by a paste of the same nature; but by whatever name we choose to designate it, its position underneath the beds of real tuff, which dip in both directions at a high angle away from the central point occupied by it, seems to indicate, that it has been ejected from beneath since the deposition of the tuff.

The subjoined woodcut, taken from a sketch given by De

Beaumont and Dufrenoy in their memoir on the volcanic formations about Naples*, will serve to illustrate the text:—



Disposition of the beds of pumiceous Tuff and of Trachytic Piperno between Pianura and the Lake of Agnano.

Its thickness indeed is unknown, but the galleries driven into it for the purpose of extracting the stone show that it extends at least forty feet beneath the surface.

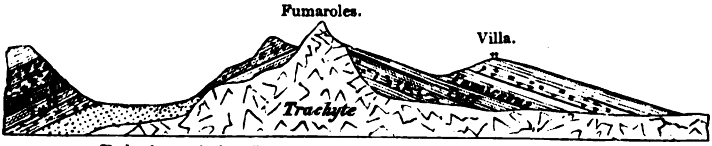
A bed of pumiceous tuff rests upon it, and a long series of others of various kinds and consistency extend to the summit of the precipitous hill of the Camalduli, dipping gently towards Naples, and presenting their perpendicular escarpments in the direction of Pianura.

A still more distinct case of the upheaving of a solid mass of trachyte is seen in the crater of Astroni, where, as above represented, we observe the beds of tuff which form the walls of the crater dipping in all directions at a high angle away from the trachytic rock in the centre.

The same disposition is observed in the crater of the Solfatara, where a trachytic rock much altered by the action of gaseous emanations forms the nucleus of the mountain.

Now in all these instances, the high angle at which the beds of tuff which mantle round the trachyte are inclined seems to show, that the latter has been protruded subsequently to the deposition of the tuff, not that the tuff was deposited round trachytic nuclei previously existing.

The subjoined woodcut from the memoir above-quoted may serve to illustrate the relative position of the trachyte and the tuff of the Solfatara:—



Relation of the Trachyte and the Tuff at the Solfatara.

* Annales des Mines, 3rd series, tom. xi.

Dufrenoy, considering that the tufaceous deposit which rises at present to so great a height must formerly have been under the level of the sea, attributes the elevation of this enormous mass to the trachyte, which has in these three instances found its way to the surface, and which he supposes to underlie the tuff.

Just as in Auvergne a vast sheet of trachyte has been heaved up in a convex form, so as to constitute the mountain groups of Cantal and of Mont Dor, so we may suppose a mass of the same material to have been uplifted underneath this portion of the Neapolitan territory, although concealed from our view, excepting in those few localities, by vast masses of superincumbent tuff.

This however is not the time to enlarge upon such points of theory; confining myself therefore to facts, I will next allude to one or two cases, in which, at a more modern epoch than the one referred to, a partial elevation of the land is supposed to have taken place.

The first of these relates to the temple of Serapis, near the town of Puzzuoli, the phænomena of which appear to indicate, that the sea has twice changed its level with reference to this coast since the Christian æra.

The facts that have led to this conjecture are,—

1st, That the floor of the temple is at present somewhat below high-water mark, and consequently exposed to the rushing in of the sea, which it is presumed was not the case when it was founded.

2ndly, That the pillars, which yet remain standing, are perforated by boring-shells (the *modiola lithophaga* of Lamarck) at a height of about sixteen feet from their base, which implies that at some intermediate period the sea-water must have stood at this level.

Now it must in the first place be conceded, that the supposition of a change of level in the land is beset with much fewer objections than the same with respect to the sea; yet even the former is not altogether without difficulties as applied to the case before us, since it seems remarkable, that the subsequent depression of the land should have so nearly coincided with the amount of its previous elevation, and that any of the pillars should remain standing after experiencing two such awful convulsions of nature.

It was to obviate these difficulties that Goëthe suggested an ingenious though rather complicated hypothesis, which with some

modifications I had adopted in the first edition of this work, as that which appeared to me upon the whole the most plausible.

Goëthe had supposed, that the existence of pholades at such a height might have arisen from the formation of a small lake on the site of the temple, ponded up above the level of the sea by accidental circumstances, and the Canonico di Jorio had appeared to point out what these circumstances might have been, by stating that the land on either side of the temple was covered with pebbles and alluvial matter to the same height as the parts of the pillars which have been perforated.

Now if this were the fact, there seemed no absurdity in imagining, that one of those volcanic eruptions, which have occurred in the neighbourhood since the temple was erected, should have so encircled the spot on which it stands, as to form a kind of basin into which the sea might have found its way, and in which pholades might have continued to live.

Nor did it appear to me, that the fact of the pavement of the temple being about a foot below the highest point which the slight tides of the Mediterranean are wont to reach, presents any further difficulty. Jorio has indeed stated that this very inconvenience was contemplated by the original builders, who erected a dyke, of which there are some remains, evidently intended to prevent the ingress of the sea*.

The site of the temple was indeed, in all probability, determined by that of the warm baths which gushed out from the spot, and the Romans were too much in the habit of controlling the movements of the sea near Baiæ by artificial barriers, to be deterred from erecting the temple on the spot which superstition dictated, by the circumstance of its being a few feet below high-water mark.

This hypothesis, which appeared to me at the period I wrote the most adequate to account for the phænomena, might perhaps even at the present time be defensible; but my chief reason for espousing it is done away, now that Professor Forbes has shown, in his excellent Physical Notices on the Bay of Naples†, that this oscillation of the surface is not a local phænomenon, but may be proved to have taken place in many contiguous spots to which the hypothesis of Goëthe cannot be extended.

I therefore am contented to set down this, as one instance amongst many of the successive changes in the level of the

* Di Jorio, pp. 55, 56.

† Brewster's Edinburgh Journal.

country, which have been brought about even in modern days by volcanic forces in the neighbourhood we are considering.

The second, and a much more decided case, which can be adduced of a change produced on the physical structure of the country round Naples by volcanic agency, was the rise of a new mountain on the northern side of the Bay in the sixteenth century. Vesuvius had at that time been for a long interval tranquil, but a succession of earthquakes had taken place in the country for two years previously. At length, on the 28th of September of the year 1538, flames, it is said, broke out from the ground between Lake Avernus, Monte Barbaro, and the Solfatara, followed by several rents of the earth from which jets of water sprung, whilst the sea receded 200 feet from the shore, leaving it quite dry. On the 29th, about two hours after sunset, there opened near the coast a gulf, from which smoke, flames, pumice and other stones, together with mud, were thrown up with the noise of thunder, and in about two days the ejected masses formed a mountain 413 feet in perpendicular height, and 8000 feet in circumference. The eruption finally ceased on the 3rd of October, on which day the mountain was accessible, and those who ascended it reported that they found on the summit a funnel-shaped opening—a crater, a quarter of a mile in circumference.

Porzio, a physician of that age, in his account of the event, states distinctly, that the land now comprehended between the foot of the mountain called Monte Barbaro, and that portion of the sea which borders upon the Lake of Avernus, was seen to be upheaved, and to take the form of a mountain : an interesting letter of a contemporary, found in a volume of the Marquis Capponi at Naples, and published in Leonhard's Jahrbuch für Geologie, 1846, completely confirms this statement.

The following is an extract from the letter, addressed by Francisco del Nero to Nicolo del Benino of Naples, sent to Rome in 1538 :—

"On the 28th of September, at midday, the sea-bottom near Puzzuolo became dry over an extent of 600 braccie (1300 yards), so that the inhabitants of the town carried off wagon-loads of fish left on the dry land. About eight o'clock in the morning of the 29th the earth sunk down about two braccie (13½ feet) in that part where there is now the volcanic orifice, and there issued forth a small stream of very cold water, as we were told by some persons we interrogated,

but others stated that it was tepid and somewhat sulphureous; as all the people whom we spoke to were worthy of credit, I am of opinion that they all spoke the truth, and that the water was at first cold and afterwards tepid. At noon on the same day the earth began to swell up, so that the ground in the same place where it had sunk down 13½ feet, by eight o'clock or thereabouts was as high as the Monte Rossi, that is, it was as high as that hill is where the little tower stands upon it; and about this time fire issued forth and formed the great gulf, with such a force, noise, and shining light, that I, who was standing in my garden, was seized with great terror. Forty minutes afterwards, although unwell, I got upon a neighbouring height from which I saw all that took place; and, by my troth, it was a splendid fire, that threw up for a long time much earth and many stones. They fell back again all around the gulf, so that towards the sea they formed a hill nearly of the height of Monte Morello, and for a distance of seventy miles round, the earth and the trees were covered with ashes. The ashes that fell here were very soft, sulphureous and heavy. They not only threw down the trees, but an immense number of birds, hares, and smaller animals were killed. I was yesterday obliged to return by sea to Puzzuolo. Many men were looking on and with amazement. Nothing was to be seen there but the hill itself; I mean nothing in comparison with what took place the preceding night when the earth swelled up, that is, at the time I came to the place. And as there was no one from Naples, and few capable of describing it, who saw the fire on that night, there is no one but myself who can make a report of it."

Now Dufrenoy informs us that the Monte Nuovo, although overed externally by scoriæ and other ejected masses nowise agglutinated, is in reality found to consist, when seen from the interior of the crater, of beds of tuff that have been upheaved; and in one of these beds Von Buch, during the Scientific Congress held at Naples in 1845, discovered, if I am rightly informed, marine shells.

I have not visited the interior of the crater since 1824, and am unable to confirm or to contradict the above statement of M. Dufrenoy; but I perceive that Professor James Forbes (Physical Notices, No. 6. p. 80) leans to the opinion of an upheaval of the mountain having taken place.

Its form is that of a compressed or oblong cone, and it has in its centre a crater almost as deep as the mountain is lofty,

the total height of which is 134 metres, whilst the depth of the crater is about 128*.

Near the bottom of the crater are one or two small caverns, the interior of which I found covered here and there with an efflorescence, having an alkaline taste. The sand at the foot of the mountain, even under the sea, possesses so high a temperature when brought up from a little below the surface of the water, that we are led to conclude the volcanic action to be still going on to a certain extent; and the same inference may be drawn from a spring, called the Baths of Nero, which gushes out from the rock in a cavern not far distant, and is sufficiently hot to boil an egg in a very few minutes †.

Some suppose that the Lucrine lake was filled up or destroyed by this eruption, but others maintain that the latter, which was a basin originally separated from the sea by a dam, had been merged in the bay again upon the decay of its embankment. It is certain that contemporary writers, in their account of the formation of the Monte Nuovo, say nothing concerning this lake.

We have hitherto been considering those volcanic phænomena which were produced in the Phlegrean fields at periods antecedent to the present, but I shall now allude to the Solfatara near Puzzuoli, a mountain, the recesses of which seem during a long succession of ages to have been the seat of volcanic action, languid indeed, but continued, although it is often regarded in the light of an extinct volcano, because no ejections of solid matter are known in historical times to have proceeded from it.

The evidences then of such operations afforded by this mountain are confined to the perpetual exhalation from it of certain gases, mixed with aqueous vapour. For an opportunity of examining the former I was indebted in 1825 to Sir John Herschel and the late Signor Covelli of Naples; these gentle-

* Dufrenoy, p. 273.

† Professor J. Forbes, who had the hardihood to penetrate to the extremity of the cavern, where the spring gushes out, states its temperature to be 182°·5. I once attempted the same enterprise, but was driven back by a sense of suffocation before I had completed half the distance, which is reckoned in all at about 120 paces.

men having been good enough, as I was incapacitated at the time by illness from revisiting the spot for that purpose, to condense for me a portion of the steam given out from one of the fumeroles in the crater, containing all the gases emitted at the same spot which water is capable of dissolving, and which appeared to consist only of sulphuretted hydrogen mixed with a minute portion of muriatic acid. In November 1834 I instituted a similar examination of the vapours, and obtained the same results, excepting that a little muriate of ammonia seemed also to be present in what I then collected.

Now, from the known chemical properties of the two gases alluded to, it may be easy to explain the presence of most of the substances found about the Solfatara.

The rock of this mountain is, as I have already stated, a trachyte, which, besides a little potass, consists essentially of silex and alumine, with an occasional admixture of iron, lime, and magnesia.

The sulphuretted hydrogen disengaged may unite with the bases of the several earths and alkalies, and form with them in the first instance the different combinations known by the name of hydrosulphurets.

Now this class of compounds undergo decomposition, when exposed to air and moisture, in two ways:—

1st. The presence of carbonic acid slowly causes the separation of the two ingredients, the several bases first combining with oxygen, and then with the acid, whilst the sulphuretted hydrogen set at liberty is at the same time resolved into its elements, of which the hydrogen forms water with the oxygen of the atmosphere, the sulphur being partly precipitated, and partly converted into the hyposulphurous acid. The hyposulphurous acid again unites with the different earthy bases, but these combinations are not permanent, but are finally resolved into sulphur and sulphates.

Hence the hydrosulphurets, so far as they are influenced by the presence of carbonic acid, give rise to the deposition of sulphur and to the formation of sulphuric salts.

2ndly. The same ultimate result appears to be obtained by the mere action of atmospheric air upon the same compounds, part of the hydrogen of the sulphuretted hydrogen abandoning the sulphur, combining with the oxygen of the atmosphere, and forming water, whilst the remainder exists in combination with a double proportion of sulphur, and produces an hydroguretted sulphuret. This sub-

stance is however finally decomposed, the hydrogen slowly combining with oxygen, and the sulphur being either oxygenized, or deposited in a solid form.

Should any of the sulphuretted hydrogen remain in its uncombined state, it will be speedily resolved into its elements by the action of air and water; for on confining a portion of this gas, either with or without an admixture of air, over water, the latter became turbid from the sulphur separated from the gas, although over mercury it seemed to remain, for a long time at least, unchanged.

It appears then, that in both these ways the compounds formed by the union of the sulphuretted hydrogen with the constituents of the rock would be finally resolved into sulphur and sulphuric salts; we have only therefore to compare this with the phænomena actually exhibited at the Solfatara.

The rock of which this mountain is composed is naturally hard and dark-coloured, but in proportion as it is exposed to the action of these vapours, its texture and colour undergo a remarkable alteration. The first stage of the process seems to be a mere whitening of the mass, in consequence doubtless of the removal of the iron to which its colour is attributable; it then is seen to become porous and fissile*; when the process is yet further advanced, it becomes honeycombed like a bone that has been acted on by the weather; and at length it crumbles into a white powder, consisting almost entirely of silex.

The saline substances that appear efflorescing on the surface of the rock, correspond with the above statements; they consist of the sulphates of iron, lime, soda, magnesia, and above all, of alumina. Breislac has given some interesting details respecting these salts, in which however I have not time to follow him; it is sufficient for our present purpose to show, that they appear in almost the same proportion as that in which they would result from the action of the same gas upon a stone similarly constituted.

Meanwhile the sulphur deposited diffuses itself through the rock, and lines the walls of its cavities; but Breislac appears to have shown very satisfactorily, that it results entirely from the sulphuretted hydrogen, and is not sublimed in an uncombined state; for we only find it in those parts of the mountain which are near enough to the surface to admit of the ready access of atmospheric air. It is accompanied with muriate of ammonia, sometimes with sulphuret of arsenic, which has probably also been disengaged, combined with hydrogen, and may contribute to the destructiveness of those exhalations which

* Mr. Scrope mentions the existence of globular concretions, like pisolites, in the decomposed trachyte, which he attributes to drops of rain falling on finely comminuted volcanic ashes.

frequently succeed an eruption. I have been assured that the paradoxical statement of Breislac with respect to the pear and olive being proof against the deleterious influence of these gases, when all other kinds of vegetables are destroyed, is not unfounded. As selenium is now ascertained to exist among the products of the crater in the island of Volcano, it appears probable that a gas, composed of that metal with hydrogen, will, ere long, be detected together with the gases before enumerated.

It may appear remarkable that muriatic compounds with the above bases are not likewise present; but if they existed, they would be immediately decomposed by the sulphuric acid generated; and that muriatic acid itself is incapable *per se* of decomposing trachyte, except it be concentrated, and the rock pounded, is shown from the fact of its continuance during so many ages in the domite of Auvergne in a free condition. Muriate of ammonia is however abundant, but its alkaline ingredient must be generated in the interior of the earth, if Liebig be correct in his opinion, that free hydrogen and nitrogen cannot be made to combine otherwise than by electricity, when both are in an elastic form.

The influence of the above exhalations is by no means confined within the compass of the Solfatara, for it extends to a considerable distance on the hills which bound that volcano towards the north, as is evinced by the whiteness and decomposed condition of the rocks, in consequence of being acted upon during so many ages by sulphureous vapours. It would appear that the ancients designated them from this circumstance under the name of the Colles Leucogæi, for Pliny* mentions medicinal waters existing between Puzzuoli and Naples, called Leucogæi Fontes; and there is still found a hot spring at a place called Pisciarelli, situated on the slope of these hills, containing much sulphate of iron and of alumina, and possessing a temperature, according to Forbes, of $112^{\circ}{\cdot}5$.

The Solfatara returns a hollow sound when any part of its surface is struck, and hence has been conjectured to be made up, not of one entire rock, but of a number of detached blocks, which, hanging as it were by each other, form a sort of vault over the abyss, within which the volcanic operations are going on.

* Hist. Nat. lib. xxxi. c. 8.

Mr. Scrope considers the reverberation merely due to the porous nature of the ground; but Professor J. Forbes supports me in the view I had taken in my former edition, remarking that the continual action of sulphureous vapours for so many centuries upon the mass of the rock, must of necessity have created chasms and hollows by the removal of so much matter from within. In the case of the Solfatara I have from the first contended, not that the sound was caused by the existence of one aperture larger than the rest, such as we are wont to suppose in the interior of every active volcano, but by a series of fissures, which allow of the escape of elastic fluids, but would prevent the fall of any bulky body.

Although we have no certain record of any eruption from the Solfatara, we observe on its south-eastern side what appears to be a stream of lava, which extends in one unbroken line to the sea, forming the promontory called the Monte Olibano, on the road between Naples and Puzzuoli. This lava is remarkable from its want of resemblance to those of most other volcanos, as it consists of a rock which can hardly, I think, be separated by its mineralogical characters from trachyte.

It is made up of crystals of glassy felspar, imbedded in a basis of a felspathic nature, having an uneven fracture and ash-grey colour, differing in these respects from the rock of the Solfatara itself, which I have found in general to possess a darker colour, and a conchoidal fracture. Both however agree in being composed essentially of felspar, and containing augite only as an occasional ingredient, so that we are obliged to class them equally under the head of trachyte, or, according to Abich, trachyte-dolerite. The stone of Mount Olibano is in general compact, but cells are sometimes present, especially in the upper part of the rock; it is seen to rest immediately on a thin bed of loose fragments of lava, and is covered by a sort of tuff, which, being placed on a part of the hill difficult of access, I left unexamined, but which I conjecture to consist of scoriæ and sand, that succeeded the ejection of the melted matter.

From a description of the volcanic phænomena exhibited to the west of Naples, we naturally proceed to the consideration of those on its eastern side, and from the semi-extinct volcano

of the Solfatara, turn with increased interest to the full development of activity displayed at Vesuvius.

The date of that part of the mountain properly called Vesuvius, or rather of its cone, does not perhaps go farther back than the period of the famous eruption of 79 after the Christian æra, in which Herculaneum and Pompeii were destroyed; for the ancient writers never speak of the mountain as consisting of two peaks, which they probably would have done, if the Monte Somma had stood, as at present, distinct from the cone of Vesuvius. It is also remarked that the distance mentioned in ancient writers as intervening between the foot of Vesuvius and the towns of Pompeii and Stabiæ, appears to have been greater than exists at present, unless we measure it from the foot of Monte Somma, so that this affords an additional probability that the latter mountain was then viewed as a part of the former, and that no separation between them had at that time occurred. We may also be sure, from the semicircular figure which the southern escarpment of the Monte Somma presents towards Vesuvius, that it constituted a portion of the walls of the original crater, and Visconti, it is said, has proved by actual admeasurements that the centre of the circle, of which it is a segment, coincides as nearly as possible with that of the present cone.

There seems therefore little room to doubt that the old mouth of the volcano occupied the spot now known by the name of the Atrio del Cavallo, but that it was greatly more extensive than this hollow, as it comprehended likewise the space now covered by the cone, which was thrown up afterwards in consequence of the renewal of the volcanic action that had been suspended during so many ages.

This view likewise tends, as I think, to reconcile the accounts which ancient writers have given of the structure of the mountain antecedently to the period before mentioned. Florus, for instance, in his narrative of the insurrection of Spartacus, describes the manœuvre by which that general contrived to escape from the Roman army, which besieged him in this mountain, in the following manner:—

"Vesuvius was the spot pitched upon for their first enterprise. Being besieged there by Clodius Glaber, they descended through the defiles of this mountain by means of

vine-twigs, and reached its very bottom, where they surprised by a sudden assault the camp of the general, who anticipated nothing of the kind*."

Plutarch, who evidently refers to the same event, notices it in a manner which perhaps will enable us to ascertain what the real structure of the mountain at that time must have been. After describing the first successes of Spartacus and his army, he says:—"Clodius the prætor was sent against them with a party of three thousand men, who besieged them in a mountain (meaning evidently Vesuvius) having but one narrow and difficult passage, which Clodius kept guarded; all the rest was encompassed with broken and slippery precipices, but upon the top grew a great many wild vines; they cut down as many of their boughs as they had need of, and twisted them into ladders long enough to reach from thence to the bottom, by which, without any danger, all got down except one, who stayed behind to throw them their arms, after which he saved himself with the rest†."

But how are these representations consistent with the account given by the accurate Strabo respecting the structure of Vesuvius, which, he says, is surrounded on all sides by fine fields, except on the summit, which is in great measure flat‡, but barren and desolate?

I know no other method of reconciling these accounts than that of supposing, that Spartacus was encamped within the crater, which occupied what is now the Atrio del Cavallo; that the walls of this crater were at that time entire, except in one part where the army of Clodius established themselves;

* "Prima velut arena viris Mons Vesuvius placuit. Ibi cum obsiderentur a Clodio Glabro, per fauces cavi montis vitineis delapsi vinculis, ad imas ejus descendere radices; et exitu invio, nihil tale opinantis ducis subito impetu castra rapuere."—*Florus*, l. iii. c. 20.

† Life of Crassus. Plutarch, ed. Reiske, vol. iii. p. 240.

‡ The following is the entire passage referred to:—

Ὑπερκειται δε των τοπων τουτων ὁρος το Ουεσουιον, αγροις περιοικουμενον παγκαλοις, πλην της κορυφης· αυτη δ' επιπεδος μεν πολυ μερος εστιν· ακαρπος δ' ὁλη· εκ δε της οψεως τεφρωδης, και κοιλαδας φαινει σηραγγωδεις πετρων αιθαλωδων κατα την χροαν, ὡς αν εκβεβρωμενων ὑπο πυρος· ὡς τεκμαροιτ' αν τις το χωριον τουτο καιεσθαι προτερον, και εχειν κρατηρας πυρος, σβεσθηναι δ' επιλιπουσης της ὑλης. Ταχα δε της ευκαρπιας της κυκλῳ τουτ' αιτιον.—Strabo, ed. Falc. vol. i. p. 355.

and that the insurgents found their ladders useful in descending some of the steep precipices which existed on the external slope of the Monte Somma, as well as in the first instance in climbing up to the brim of the then existing crater. The western front looking towards Naples being broken away, Strabo might naturally have considered what was once the interior of the then extinct crater as the summit of the mountain, and it is by no means unlikely, that the former may in his time have possessed that level surface which he notices as the general character belonging to it. At all events no alternative seems to exist between this explanation, and our regarding the passage as inaccurate, for the structure of the Monte Somma is such as plainly demonstrates, that it has not been thrown up by any subsequent eruption, but existed at least at its present elevation in the period to which Strabo alludes*.

The preceding remarks may be considered as bringing down the history of the volcano to the commencement of the Christian æra, when so long an interval had elapsed since the time at which it was last in activity, that no certain record of any preceding eruptions appears to have existed.

It is true that Diodorus Siculus, who, from having visited Etna, must have been familiar with volcanic appearances, was struck with the indications of a similar origin which he perceived in Vesuvius†; and we also find that Vitruvius, when speaking of the Puzzolana near Naples, which he supposes to have been formed by heat, notices a tradition that Vesuvius also in former times emitted flame. Lucretius likewise has been supposed to refer to this mountain in his 6th Book, where he speaks of a spot near Cumæ which sends forth sulphureous fumes; but little ought to be built on a passage which has such different readings‡, and it seems just as pos-

* See Plate I., at the end of the volume, representing Vesuvius, as it now is, and as it is supposed to have been in the time of Strabo.

† *Ωνομασθαι δε και το πεδιον τουτο Φλεγραιον, απο του λοφου του το παλαιον απλετον πυρ εκφυσωντος, παραπλησιως τῃ κατα την Σικελιαν Αιτνῃ· καλειται δε νυν ὁ τοπος Ουεσουιος, εχων πολλα σημεια του κεκαυσθαι κατα τους αρχαιους χρονους.*—Lib. iv. c. 21.

‡ This passage is very differently read :—

sible that the poet may have meant to allude to the exhalations of the Solfatara, which lies much nearer to Cumæ: nor is Silius Italicus, who has been quoted in proof of an eruption having taken place during the second Punic war, an authority altogether unquestionable, since having witnessed the famous eruption of 79, he may, by a very natural poetical licence, have introduced a similar event as happening at an earlier period, without any direct sanction from history.

On the other hand, it may be remarked, that Strabo seems rather to infer the igneous origin of Vesuvius from the nature of the rocks found upon it, than from any received tradition, and that it seems natural to attribute to the mountain a long period of tranquillity, both from the cultivated state in which it existed*, and from the circumstance of the crater having been effaced on one side, as must be understood to have been the case, if we suppose that it was the spot having only one outlet in which the army of Spartacus was besieged†.

This period of apparent security was however at length to cease; in the year 63 after Christ the volcano gave the first symptom of internal agitation, in an earthquake which occasioned considerable damage to many of the cities in its vicinity, a curious proof of which is exhibited by the excavations made at Pompeii, showing that the inhabitants were in the very act of rebuilding the houses overturned by the preceding

Is locus est Cumas apud; acri sulfure montes
Oppleti calidis ubi fumant fontibus aucti:

or,

Qualis apud Cumas locus est montemque Vesevum,
Oppleti calidis ubi fumant fontibus, auctus.

It is evident that even the latter reading affords no proof that Vesuvius had experienced any recent eruption, or was in a more active state than the Solfatara of Puzzuoli, which will be afterwards mentioned.

* See Virgil's Georgics, Martial, Varro, and others.

† If Mr. Hayter be correct in deriving Herculaneum from Her and Koli, *the burning mountain*, we might obtain an additional argument in favour of the ancient eruptions of Vesuvius; but it is an evident affectation to substitute a far-fetched etymology for one so obvious as that which derives it from Hercules: and even admitting the former to be the correct derivation, it affords perhaps no stronger proof, than the names of some of the mountains in Auvergne and Hungary do, of the modern date of their eruptions. In both cases the aspects of the spots themselves might be sufficient to suggest the application of their names.

catastrophe, when their city was finally overwhelmed in the manner I am about to describe.

On the 24th of August of the year 79, the tremendous eruption took place, which has been so well described in the letters of the younger Pliny*. It was preceded by an earthquake which had continued for several days, but being slight had been disregarded by the inhabitants, who were not unaccustomed to such phænomena. However, on the night preceding the eruption, the agitation of the earth was so tremendous as to threaten everything with destruction.

At length, about one in the afternoon, there was seen in the direction of Vesuvius, a dense cloud, which, after rising from the mountain to a certain distance in one narrow vertical trunk, spread itself out laterally in a conical form, in such a manner that its upper part might be compared to the branches, and its lower to the trunk, of the fir which forms so common a feature in the Italian landscape†. It was descried from Misenum, where the elder Pliny, as commander of the Roman fleet, happened to be stationed with his family, among whom was his nephew, the author of the letters referred to. The latter, who seems already to have imbibed somewhat of the spirit of the Stoical philosophy, which inculcated rather an indifference to the course of external events than an inquiry into their nature, pursued his usual train of studies as before; but the former, with the zeal and enterprise of a modern naturalist, prepared, in defiance of danger, to obtain a nearer view of the phænomena, as well as to render assistance to the sufferers.

Accordingly he first repaired to Resina, a village immediately at the foot of Vesuvius, but was soon driven back by the increasing shower of ashes, and compelled to put in at Stabiæ, where he proposed to pass the night. Even here the accumulation of volcanic matter round the house he occupied rendered it necessary for him to remain in the open air, where it would appear that he was suddenly overpowered by some noxious effluvia; for it is said, that whilst sitting on the seashore under the protection of an awning, flames, preceded by a sulphureous smell, scattered his attendants, and forced him to rise supported by two slaves, but that he quickly fell down, choked, as his nephew conjectured, by the vapour,

* Plin. Epist. lib. vi. Ep. 16, 20.

† The Stone Pine, *Pinus Pinea*, is the species probably referred to.

which proved the more fatal from the shortness of breathing under which he laboured. The absence of any external injury proves that his death was caused by some subtle effluvia, rather than by the stones that were falling at the time, and it is well known that gaseous exhalations, alike destructive to animal and vegetable life, are frequent concomitants of volcanic eruptions.

The other circumstances of this memorable event are sketched by the younger Pliny with a rapid but masterly hand. The dense cloud which hovered round the mountain, pierced occasionally by flashes of fire more considerable than those of lightning, and overspreading the whole neighbourhood of Naples with darkness more profound than that of the deepest night; the volumes of ashes which encumbered the earth, even at a distance so great as that of Misenum; the constant heaving of the ground, and the recession of the sea, form together a picture, which might prepare us for some tremendous catastrophe in the immediate neighbourhood of the volcano—and that this catastrophe did occur, modern investigations have fully demonstrated.

There can be no doubt, that the cities of Stabiæ, Pompeii, and Herculaneum, with probably many minor places situated on the slope, or in the vicinity of Vesuvius, were destroyed during this eruption, although it has been regarded as singular, that the author of the letters alluded to refers to this disaster only, as it were, parenthetically, amongst other circumstances calculated to perpetuate the remembrance of the manner of his uncle's death *. Pliny however professes to have nothing farther in view than to supply the great historian who he wished should undertake his uncle's biography, with such particulars as were connected with the death of that individual; he distinctly disclaims all intention of communicating any general account of a catastrophe, which had happened some years before his letter was written †, and was therefore already of general notoriety.

* "Quamvis enim pulcherrimarum clade terrarum, ut populi, ut urbes memorabili casu, quasi semper victurus occiderit, quamvis ipse plurima opera et mansura condiderit, multum tamen perpetuitati ejus scriptorum tuorum æternitas addet."—*Plin.* lib. vi. Ep. 16.

† From his stating that he was in his eighteenth year at the time of the catastrophe, I infer that the letter was written some time afterwards. "In-

Tacitus however can refer to nothing else than this, when he speaks of the cities swallowed up or overwhelmed in Campania*; Martial contrasts the desolation produced by this eruption with the smiling aspect borne by the mountain previously†; Suetonius alludes to the benevolence evinced by Titus in the case of the sufferers from the event‡; Plutarch, 104 years afterwards, speaks of the emission of fire from the mountain, the ejection of rocks, and the burying of many cities, now, he says, so completely lost, that no vestige of them exists;§ Statius, with a prophetic spirit, asks, if posterity will believe that cities and their populations lie entombed under what shall become hereafter green fields and fertile corn land ||; and, above all, Dion Cassius, who lived about a century and a half afterwards, gives us several fresh particulars relating to the catastrophe, mixed up with certain fabulous traditions connected with it¶.

All the specimens of antiquity indeed which have been recovered from the lost cities, point to an age not later at least than that of Titus. None of them betray symptoms of that decline of art, which would have been evident had they been entombed at a later period.

The covering indeed of three entire cities under a heap of ashes from 60 to 112 feet in depth, would seem an effort al-

terim Miseni ego et mater: sed nihil ad historiam, nec tu aliud quam de exitu ejus scire voluisti."—*Plin.* lib. vi. Ep. 16.

* "Haustæ aut obrutæ urbes fœcundissimâ Campaniæ orâ."—*Hist.* lib. i. ii.

† Hæc Veneris sedes Lacedæmone gratior illi,
Hic locus Herculeo nomine clarus erat.
Cuncta jacent flammis et tristi mersa favillâ.

‡ In vitâ Titi, c. 8.

§ De Pythiæ Oraculis.

|| Hæc ego Chalcidicis ad te, Marcelle, sonabam
Littoribus, fractas ubi Vesvius egerit iras,
Æmula Trinacriis volvens incendia flammis.
Mira fides! credetne virûm ventura propago,
Cum segetes iterum, cum jam hæc deserta virebunt,
Infra urbes populosque premi?—(lib. iv. 78.)

¶ He tells us that during the eruption a multitude of men of superhuman stature, resembling giants, appeared, sometimes on the mountain and sometimes in the caverns; that stones and smoke were thrown out, the sun was hidden, and then the giants were heard, &c.; and finally that two entire cities, Herculaneum and Pompeii, were buried under showers of ashes, whilst the people were sitting in the theatre.—Life of Titus.

most too gigantic for the powers of this single mountain, if we were not aware of the vast depth at which volcanic operations take place, and the immense extent therefore over which their influence may be supposed to reach. It has been calculated, that the masses ejected at different times from Vesuvius vastly exceed the whole bulk of the mountain*; and yet the latter seems upon the whole to undergo no diminution, for the falling in of its cone at one period is at least balanced by the accumulation of ashes at another.

Now the cities of Stabiæ, Pompeii, and Herculaneum, which were destroyed in the course of this eruption, appear to have been overwhelmed, not by a stream of melted matter, but by a shower of scoriæ and loose fragments of volcanic materials†; for the various utensils and works of art that have been dug from thence nowhere exhibit signs of fire, and even the delicate texture of the papyri appears to have been affected, only in proportion as it had subsequently been exposed to air and moisture. Thus in those at Pompeii, which was covered by a mere uncemented congeries of sand and stones, decomposition has proceeded so far that their contents are illegible, whereas at Herculaneum the characters often admit of being deciphered, from their having been preserved under a species of tuff. The formation of this latter substance has been explained on the supposition of the ejections of the volcano having been accompanied in this quarter by a torrent of mud, which, favouring the agglutination of the loose materials, reduced them to a state, less consistent indeed than tuff generally is, but yet capable of preventing in some degree the access of air and humidity to the substances underneath. Sir W. Hamilton notices a fact, which shows very conclusively, both that the tuff of Herculaneum was once in a pasty state, and that it owed its softness not to heat but to moisture, the head of a statue that was dug up having left a cast in the tuff which had formed upon it, without appearing to be itself in the least scorched.

* This was remarked even by the ancients, and Seneca, Letter 79, after starting the difficulty, solves it by remarking that the fire of the volcano "in ipso monte non alimentum habet, sed viam."

† The stones that fell at Pompeii are said many of them to weigh 8lbs., the largest of those at Stabiæ only an ounce.

A remarkable discovery has been made by Ehrenberg with respect to the existence of Infusoria in the pumice and sand which covered Pompeii, as well as in a vast variety of similar formations. The Infusoria are here, as in most other localities hitherto examined, of freshwater origin, and their appearance would seem to indicate, either that the material from which the pumice was derived had been produced by successive generations of these minute animalcules, or had for a long time constituted a suitable *nidus* for their growth. It shows also that any degree of heat, below that productive of absolute liquidity, and consequently of a state of actual vitrifaction in the volcanic material, is compatible with the preservation of the organic forms of these bodies. Obsidian, basalt, and greenstone indeed do not appear to contain any indications of the kind, but a degree of temperature sufficient even to generate crystals of *augite* has not, in some cases referred to by Ehrenberg, obliterated the siliceous casts of these Infusoria*.

Considering therefore the near relation which probably exists† (chemically speaking) between the pumice and the tuff of this neighbourhood, I should regard the former as produced from the latter by the influence of a degree of volcanic heat, insufficient to destroy the infusorial casts with which the materials had been charged whilst still remaining under water—a supposition which, encumbered as it may be with difficulties, will be viewed perhaps as less extravagant, than the idea of any kind of organic being continuing to live in the interior of the earth, and within the very focus of a volcano.

Mr. Lyell indeed has suggested another possible explanation, by supposing that water charged with these animalcules comes into contact with the pumiceous rock, and on evaporation leaves its animalcules behind; but the infinite number of these infusorial shields, and the thorough incorporation of them with the containing rocks, are opposed to such an hypothesis, which would also imply that the water by which the fires of a volcano are fed proceeds from freshwater lakes, whereas numerous facts point to the sea as its true source.

* See for a full detail of these new discoveries the Quarterly Journal of the Geological Society for August 1846.

† See the second chapter.

The derivation however from tuff of the pumice which covers Pompeii is only proposed as a matter of pure conjecture, but not so the origin of the material in which Herculaneum has been entombed. We can more confidently speak of this, as derived from the tuff with which the flanks of the old crater of Vesuvius up to a certain height consist, for the violent rains which accompany most eruptions, or perhaps the bursting of a lake which may have occupied the crater, might have caused some part of this incoherent material to be washed down, and thus have deluged the city with a mud eruption similar to the *Moya*, which will be described hereafter, when we speak of the volcanos of the New World.

When at Naples in 1834, I visited some excavations which were going on just above the level of the sea, below the town of Torre del Annunziata, connected with a newly-discovered warm spring, remarkable for the copious disengagement from it of carbonic acid gas. As the buildings discovered were Roman, it is natural to refer their interment to the same epoch as that of Pompeii and Herculaneum, and what appears best to correspond with the position of the place is the town or village of Oplonti, mentioned in the Tabula Theodosiana.

In this document there is attached to the name Oplonti the drawing of a quadrangular building, and in another part of the same map, where a similarly shaped edifice is delineated, a thermal spring is implied to have existed on the site. It is probable therefore, that the warm spring recently discovered was known to the Romans, and that the place called Oplonti was connected with the establishment.

The section above the spring further shows, that the place has been overwhelmed by some other eruption subsequent, for 10 feet above the buildings alluded to is a bed of lapilli, containing the roots of a cypress, which stood upright in the soil, and is imbedded in tuff, the outer part carbonised, the interior perfectly sound. From the level of this tree to the summit of the cliff is a distance of 34 feet, the whole of the matter composing which would appear to have been deposited prior to the year 572 of the Christian æra, since a coin bearing that date has been discovered in the immediate neighbourhood a few feet under the soil.

Whilst therefore we refer the interment of the Roman buildings near the bottom of the cliff to the eruption of 79, we must attribute the overlying layers of tuff and scoriæ to another which was subsequent to it, but yet prior to the ninth century.

It is not my intention to go through all the subsequent eruptions which have taken place from this volcano in detail, since the accounts that have been handed down respecting them present for the most part little more than vague pictures of the terror and desolation occasioned, without serving to increase our knowledge of the phænomena themselves.

The second eruption appears to have happened in the year 203, under the Emperor Severus, and is described by Dion Cassius and Galen; the third in the year 472, which is said by Procopius to have covered all Europe with ashes, and to have spread alarm even at Constantinople*. Other eruptions are recorded as having occurred in the years 512, 685, and 993.

In none of the accounts that have reached us of the above eruptions do we hear of anything having been ejected excepting ashes and rapilli; but in the next, which occurred in 1036, there appears to have been likewise an eruption of lava, which is stated to have issued not only from the summit, but also from the sides of the cone, and to have reached the sea.

Between that date and the commencement of the seventeenth century, the volcano is only stated to have been five times in a state of complete activity, namely in 1049, 1138, 1139, 1306, and 1500; for the next recorded eruption was in 1631: so that 131 years elapsed between this and the one preceding it, as well as 167 years between that in the twelfth and fourteenth centuries, if we can depend upon our information regarding this dark period of history.

Accordingly in the interval between the eruptions of 1500 and 1631 the mountain put on the appearance of an extinct volcano, the interior of the crater, according to Braccini, being in 1611 covered with shrubs and rich herbage, the plain called the Atrio di Cavallo overgrown with timber and sheltering wild animals, whilst in another part there were three pools, two of hot, and one of cold water, and two of these impregnated with bitter salts.

* Silius Italicus aptly compares the flight of Hannibal's soldiers after the great battle of Zama into regions of Africa where the Carthaginian name had never been heard of, to the appearance of the ashes of a volcano in places far removed from the site of its eruptions (lib. xii.).

As to the cone, which was then six miles in circumference, its sides rose 350 feet above the plain just mentioned, and were steep and barren, whilst on the summit was a large circular lake of great depth.

It is remarkable that during this interval of repose the elevation of the Monte Nuovo occurred, as if the volcanic activity had been temporarily transferred to another quarter.

Such are a few of the particulars related with regard to the condition of Vesuvius previous to the great eruption of 1631, which covered with lava the greater part of the villages lying at its foot on the side of the Bay of Naples, and destroyed 4000 people. Torrents of water also issued from the mountain, and completed the work of devastation. The volcano is likewise said to have been in activity in the years 1660, 1682, 1694, 1697, and 1698, from which time till the present its intervals of repose have been less lasting, though its throes perhaps have diminished in violence; for the longest pause since that time was from 1737 to 1751, and no less than eighteen distinct eruptions are noticed in the course of little more than a century, several of which continued with intermission for the space of four or five years. That of 1737 gave rise to a stream of lava, which passed through the village of Torre del Greco, and continued its course until arrested by the sea, at which time its solid contents were estimated at 33,587,058 cubic feet.

The eruption of 1760 was remarkable as having proceeded, not from the cone itself, but at a great distance from it on its southern flank, about one mile above the convent of the Camalduli. Over the three openings from whence three distinct streams of lava at that time proceeded, three truncated conical craters were thrown up, which still exist, and are called Vocali or Viuli, the interior cavity of the smallest of which is forty feet deep. One of the currents approached within twelve paces of the sea near Torre del Greco.

Of the later eruptions one of the most formidable was that of 1794, recorded by Breislac, himself an eye-witness of it, in his travels in Campania. The torrent of lava that proceeded from it again destroyed the town of Torre del Greco, and advanced into the sea to the distance of no less than 362 feet, with a front of 1127. The cubic contents of this single

current are estimated by that naturalist at 46,098,766 cubic feet.

The eruption of 1813 has been described by Menard de Groye, and that of 1822 by Monticelli, which may be singled out for our especial study, not as being in themselves of more importance than the rest, but as having been illustrated by more competent observers.

It is indeed only of late that any facts appear to have been obtained, from an observation of these phænomena, that promise us the least insight into their real nature, owing to the mistaken course pursued by our forefathers in taking account only of the grander operations of the volcano, which in reality are of all others the least instructive, from being accompanied with circumstances of terror and risk, precluding the possibility of near and accurate research. As the chemist, in the investigation of a new substance, will often light upon properties, when operating on a single grain, which had escaped his notice when embarrassed with a larger quantity, so it may often happen that the minor eruptions of a volcano, which vulgar observers overlook, reveal to us phænomena that had been unperceived amidst the terror and confusion of its more violent commotions; and if the naturalist be disappointed in witnessing the effects on a less magnificent scale than he could have desired, he will be amply repaid by being enabled to investigate them, at a time when no considerations of a personal nature control or interrupt his proceedings. Nevertheless, as every *degree* of energy in the volcanic processes may be expected to give rise to certain new phænomena, an account should be taken of the circumstances that present themselves on the mountain from a state of the most languid to that of the most vigorous action, and it is only by combining observations made during a considerable period, such as may include all these varieties of condition, that we can hope to obtain correct data on which to build a theory of volcanic operations.

Now from the year 1822 we may glean something more approaching to a connected history of the volcano, although nothing that can be compared with that diary of its operations, which, it is to be hoped, will be henceforward preserved, now that the king of Naples has erected on the flanks of

Vesuvius above the Hermitage, a meteorological observatory, which, it is said, is to be placed under the care of the celebrated Melloni.

Previously to the year 1822, there had been formed in the interior of the great crater by the gradual accumulation of scoriæ and fragments of rock, a cone which possessed an elevation greater than that of the Punta di Palo, the summit of the Monte Somma. The whole of this was blown into the air by the eruption of that year, and a hollow existed in the crater not less than 800 feet in depth.

Such was the state of the volcano when I visited it in its then tranquil condition, for the first time in 1824, the interior of the crater being at that time inaccessible from the steepness of its sides, even if it had not been unapproachable, owing to the copious evolution of steam and sulphureous gases at that time filling the cavity.

In March 1827 a small cone began to form at the bottom of the great crater, and this continued to throw up scoriæ with greater or less activity during the two succeeding years.

In May 1830 this cone was 150 feet above the brim of the crater, and from that time it went on enlarging in bulk and height till August 1831. On the 14th of that month there was the shock of an earthquake, followed by much steam, sand and lava, which remained within the crater. On the 18th of the September following the lava burst forth, and on the 20th flowed rapidly down the mountain in the direction of Bosco Reale. The eruption continued till the end of the following February.

The effect of the eruption of 1831 was to clear the crater in great measure of the accumulated mass of scoriæ contained within it, but soon afterwards two new cones began to be formed in its interior by fresh ejections of volcanic matter.

In the month of August 1834* these cones disappeared, being swallowed up apparently within the recesses of the mountain. About the same time lava began to flow from the western side of the crater, and subsequently a more powerful stream issued from a point outside the crater on the eastern side of the mountain.

* See my account of this eruption in the Philosophical Transactions for 1834.

This, swelled by several other currents proceeding from adjoining points, descended the slope of the mountain until it reached Mauro, sweeping away with it the village and part of the casino of the prince of Ottayano, and blocking up the road.

Widening as it descended, the current had acquired, by the time it reached the base of the mountain, a breadth of nearly half a mile, although its depth averaged from fifteen to eighteen feet; so great was the quantity of lava emitted, by the abundance of which, no less than by the violence of the accompanying explosions, this eruption was distinguished.

Arriving at Naples in the month of November, I examined the lava stream, which though hard, at least on the surface, still retained a part of its original heat; for a thermometer placed upon the bed of lava, after the scoriæ on the surface had been removed, speedily rose to 390° of Fahrenheit; and similar indications were obtained by means of a pyrometer of Daniell's construction, introduced into a cavity in the *coulée*.

Yet, notwithstanding the high temperature at which it had issued from the interior of the earth, and that which it still retained, after a period of four months, the lava continued to emit from numerous cracks and crevices much aqueous vapour, impregnated with free muriatic acid and with muriate of ammonia coloured by iron. As these volatile bodies were evidently entangled in the lava itself, and did not proceed from the ground on which the latter rested, I can only account for the phænomenon by a kind of adhesive affinity subsisting between the mass of lava and the substances which were thus disengaged.

Early in 1839 a vivid eruption took place, which continued for four days, in which the points most worthy of notice were, the extraordinary quantity of scoriaceous lapilli which fell, more especially at Torre del Greco and Torre del Annunziata, and likewise the two currents of lava which poured over the crater, one taking the road of the Fossa Grande, the other flowing in the opposite direction towards Ottayano.

After such an eruption, the crater, cleared of its contents, acquired the form of a deep funnel, accessible to its very bottom, and it continued from that time tranquil till the autumn of 1841, when a small cone began to form in it,

through a succession of small ejections. This cone* continued to increase up to the time I visited it in the autumn of 1845, at which time it had acquired such an elevation, that its summit was distinctly visible from Naples above the brim of the crater in which it was placed. The cause of this increase was evident, as every three or four minutes there took place from its top an explosion of red-hot stones, which falling for the most part upon the external slope of the cone, tended at once to enlarge and to elevate it.

On the 22nd of April in that year, a remarkable ejection of fine crystals of leucite from a narrow stream of lava near the base of the small cone took place †. Their infusibility caused them to preserve their crystalline form, though ejected together with lava which was itself in a melted condition.

Products of Vesuvius.

Having brought the history of Vesuvius down to the present day, I shall next consider the nature of the products which have from time to time resulted from its internal operations.

These in the former edition of my work I classified under the three heads of—its lavas—its ejected masses—and its gaseous exhalations; meaning by the first to include all those substances which formed the great mass of the mountain; by the second those which occur in small quantities intermixed with the former, its staple products; and by the third, all those substances which are emitted in a gaseous condition from the volcano, whether existing in a permanently elastic form afterwards or not.

Retaining the same order of considering the subject, I shall begin by describing the actual structure of the mountain, and the characters of its predominant constituents.

If we may judge by the section laid bare by the great fissure extending down the slope of Monte Somma, called the Fossa Grande, the whole of that mountain to the height of 1500 feet is made up of inclined beds of pumiceous tuff,

* In 1843 it was described by M. Rozet, in the Bull. Soc. Géol. vol. i. new series, and Edinb. Journ. of Science, p. 1844.

† See a memoir by Professor Scacchi of Naples.

sometimes composed of loose fragments uncemented, sometimes as coherent as the tuff of Posilippo.

The tuff may be traced in this part of the mountain as high as the Hermitage, and there can be but little doubt that it extends round the entire mountain to about the same level, although in other parts for the most part concealed by the streams of lava and ejected masses that have since proceeded from the modern cone of Vesuvius. Like the tuff of Puzzuoli, it contains marine shells, such as exist in the Mediterranean at the present day, and the limestone blocks which it incloses have been even found to have attached to them serpulæ, which, in spite of their extreme delicacy, are nowise damaged, as would have been the case if they had been ejected from the volcano.

Above the Hermitage we meet with a series of compact beds, which Dufrenoy regards as the ancient lavas of Monte Somma, separated one from the other by layers of scoriæ. They constitute the semicircular crest of rocks, which are the remains of the ancient crater, and which, if continued round that side of the mountain which looks towards the Bay, would entirely encircle the cone of Vesuvius. These beds appear horizontal when seen from within, but this arises from their edges merely being visible, for the exterior slope of the mountain, which is inclined at an angle of about 25°, is caused by that of the beds composing it, which dip on all sides away from its centre.

The beds are composed of a paste, including crystals of augite, leucite, and glassy felspar. Dufrenoy regards the paste also as consisting of leucite, and it is at least certain that, in common with the leucitic crystals, it contains a large proportion of potass. The beds are in general very regular in thickness, and uniform in texture, and are intersected by dykes consisting, like themselves, of a kind of leucitic porphyry, but with a paste of a more compact character and of a finer grain, and with crystals of leucite more regular in form and considerable in point of size, than those in the beds they intersect.

These dykes are sometimes observed to terminate above, and at other times below, nor are there wanting cases in which they seem altogether inclosed in the substance of

the rock. Unlike most other dykes, they neither produce any change in the position of the beds, nor in the character of the rock with which they are in contact.

The following will give an idea of the dykes of Monte Somma, and their connexion with the rock which they traverse.

Dykes of Monte Somma, Vesuvius.

Whatever theory we may adopt with respect to the formation of the beds in which these dykes occur, it is probable that we shall all concur in considering them produced by the injection of a leucitic lava into cracks which previously existed in the containing rock.

The semicircular crest of the Monte Somma is separated from the cone of Vesuvius by a valley called the Atrio di Cavallo, which is covered over by streams of lava that have flowed from the present volcano.

The cone of the latter consists of lavas and ejected masses, altogether differing in mineralogical character and chemical constitution from the products of the Monte Somma.

The last-named mountain, as we have seen, contains much leucite, and is consequently rich in potass; whilst Vesuvius is totally destitute of this mineral according to Dufrenoy, although this is disputed by Abich, both of whom however agree in assigning to it a much larger amount of soda than is present in the Monte Somma *.

* Accordingly whilst the lavas of Monte Somma are nearly insoluble in acids, those of Vesuvius generally are dissolved in muriatic acid in the

The composition of the several streams is upon the whole pretty uniform; but their compactness varies much, according to the angle at which they had to descend, and the consequent rate of their movement.

Dufrenoy and Elie de Beaumont have endeavoured to establish, that no lava current which has flowed down an inclination of more than two degrees ever assumes a crystalline texture; when the inclination is greater than this, the whole mass consists of incoherent and scoriaceous fragments; and in cases where it is very steep, obtains that ropy consistence which is so remarkably seen on the surface of many.

It is only when the stream reaches a nearly level surface, that the inferior portion of the mass can acquire a stony aspect and a structure approaching to the columnar, the upper surface remaining cellular or scoriaceous.

Such is the case with the lavas of Granitello and La Scala situated on the sea-coast, the first near Resina, the latter on the road to Torre del Greco, the appearance of which latter reminds one a little of those prismatic forms which basalts of the older trap formations so frequently assume.

Now this circumstance alone establishes, in the opinion of these distinguished French geologists, a marked line of demarcation between the lavas of Somma and of Vesuvius; for as the former are compact and crystalline, it is to be inferred, that they cannot have flowed down a slope equal to that which the greater part of the Vesuvian lavas have descended; and hence, as their beds are at present inclined at an angle of more than twenty degrees, they must have been upheaved subsequently to their emission.

Nor are evidences of upheaval limited to the leucitic rocks which constitute the summit of Monte Somma, for as we have seen, the tuff underneath would seem, from its resemblance to that of Posilippo, and from the existence in it of marine shells, to have been once at the bottom of the sea, so that it must have subsequently been subjected to the same elevatory movement which the former appear to have undergone.

The full discussion of this question is reserved for a future page; but it would be improper to conceal from my

proportion of four to one. See his 'Parallèle entre les différens Products Volcaniques de Naples,' &c. in the fourth vol. of the 'Mémoires pour servir à une Déscr. Géol. de la France.'

readers the fact, that the theory above stated has met with many determined opponents both in France and in England.

It may be remarked however, that Mr. Lyell, the most prominent of those who have objected to it in this country, admits the probability that the greater part of the beds of the Val di Bove in Etna, to which the same argument applies as to those we have been just considering, were originally less inclined than they are seen to be at present.

This admission on his part narrows the field of dispute greatly, and leaves it open to us either to adopt the elevation theory of Von Buch as applicable to these volcanos, or the step-by-step upheavement which is the other alternative, according as we are most disposed to adopt the notion, of paroxysmal eruptions alternating with long periods of tranquillity, or of the long-continued operation of existing forces acting only with their present intensity.

Without denying that the former theory, as applied to Vesuvius, is attended with some difficulties, I conceive that the objection, *in limine,* which has been alleged against our entertaining it, on the ground that it would be unphilosophical to ascribe a different mode of formation to Monte Somma, from that which we witness going on before us at Vesuvius, seems removed, if it can be shown that the products of the two mountains are different both in texture and in chemical composition, and therefore have been produced under two different conditions.

An opposite view of the structure of Monte Somma has however been taken by M. Necker de Saussure in an interesting Memoir published in the 'Transactions of the Academy of Geneva,' and a similar explanation of it is offered by Mr. Scrope in his 'Considerations on Volcanos;' these however I need not do more than allude to, as they have been fully put before the public in Mr. Lyell's 'Principles of Geology,' a work which is in the hands of all who interest themselves in such subjects.

From the materials which constitute the great bulk both of the ancient and modern volcano, let us next turn to the consideration of what I have called *the ejected masses*—not meaning by that term the fragments of various sizes, which being thrown up into the air, descend in a solid form and

accumulate round the orifice—for these, though in a more cellular condition, agree in chemical characters with the lavas of the same epoch—but those extraneous bodies which are found scattered amongst the staple products of the volcano.

Those that may be referred to the ejections of Monte Somma are of peculiar interest. They are accumulated in the Fossa Grande and other hollow ways on the slope of the mountain, where torrents have exposed a section of the several beds. I have collected in these situations a series of granular limestones, nowise inferior in the fineness of their grain to those found in primitive districts, yet the only calcareous rock met with in the neighbourhood is the coarse limestone of the Apennines, and it seems therefore not altogether improbable, that the conversion of this stone into marble may have been effected by volcanic agency*. Breislac mentions, that Dr. Thomson observed the same change to take place sometimes in calcareous stones exposed to the heat of a lime-kiln, and that a specimen of that kind, one half of which is common limestone, the other marble, is at present among the specimens bequeathed by that naturalist to the University of Edinburgh†.

The variety of mineral species enumerated by Signors Monticelli and Covelli as found by them amongst the ejected masses appeared to be so great, that in the former edition of this work I abstained from any mention even of their names.

Subsequently however, the present intelligent Professor of Mineralogy at Naples, Scacchi, has shown, that many of these are mere synonyms or varieties of other species, and thus has succeeded, although the discoverer of several new minerals at Vesuvius, in reducing the whole catalogue within a moderate compass.

The following then is the table which he has given, in

* Cornelius Severus, in his spirited poem on Etna, has happily expressed the distinction between the substances to which the volcanic fire has given new properties, and those which it has only partially affected—

Pars igni domitæ,—pars ignem ferre coactæ.

The existence of magnesia in most of these specimens is a circumstance well-worthy our attention, as it does not seem to be common in the limestone of the Apennines.

† Breislac, Institut. Geol. § 255. The fact is rendered more probable from the researches of Faraday, who has shown that carbonic acid cannot be expelled from limestone unless steam be present.

which those minerals which are found at Monte Somma, and the modern part of the mountain distinguished as Vesuvius, are duly specified.

Minerals found about Vesuvius.

V. Modern Vesuvius. S. Monte Somma. Sc. Scoriæ.
E. B. Erratic Blocks. L. Lavas. D. Dykes.

Name of Mineral.	Where found.	Locality.
Fluate of lime	E. B.	S.
Phosphate of lime	E. B. and L.	S.
Carbonate of lime	E. B.	S.
Carbonate of magnesia (Giobertite)	E. B. very rare.	
Arragonite	E. B. and D.	S.
Zircon	E. B.	
Peridote (Monticellite)	E. B.	
Wollastonite	E. B.	
Augite	L.	S. and V.
Hornblende	E. B. Sc.	S. V.
Breislakite	L.	V.
Humite	E. B.	S.
Leucite	E. B. L.	S. V.
Meionite	E. B.	S.
Sarcolite	E. B.	S.
Mellilite	L.	S.
Humboldtite (Zurlite, Somervillite)	E. B.	S.
Sommite (Nepheline, Davyne, Cavolinite)	E. B.	S.
Glassy felspar*	E. B.	
Anorthite (Christianite, Biotine)	E. B.	S.
Idocrase	E. B.	S.
Garnet	E. B.	S.
Hauyne	E. B.	S.
Sodalite (most frequent)	L.	V.
Lapis Lazuli	E. B.	S.
Comptonite	E. B.	
Stralcime	E. B.	
Gismondine	E. B. and D.	S.
Mica	E. B. L.	S. V. *rare*.
Sulphuret of arsenic	in the Fumaroles.	
——— of lead	E. B.	S.
——— of zinc	E. B.	S.
——— of copper	in the Fumaroles.	
Pleonaste	E. B.	S.
Oxidulated iron	E. B.	S.
Hydrate of iron	E. B. and D.	S.
Sulphuret of iron and copper (Calcopirite)	E. B.	
Liver-coloured pyrites	E. B.	
Nigrine †.		
Sphene	E. B.	

In explanation of the term *Erratic Blocks,* I may remark, that amongst the loose fragments of the Fossa Grande, por-

* Commoner in the *trachytic* than the *leucitic* products.

† Sand of the shore near Vesuvius.

tions of volcanic matter seem to have been detached from some torrent of lava that lay within the sphere of the volcanic operations; these disrupted masses are called Erratic Lavas, to express at once their supposed origin, and to separate them from such as constitute a part of some existing current.

It appears from this statement, that the greater number of the above minerals are confined to Monte Somma, and that the only ones at present known to be produced by Vesuvius are, augite, hornblende, breislakite, mica, magnetic iron, sodalite, and more rarely leucite, if indeed the latter be not merely ejected.

The gaseous exhalations given off by Vesuvius both in 1834 and in 1845, when I made them the subject of a particular examination*, proved to be muriatic acid and aqueous vapour; but on neither of these occasions could the mountain be regarded as in a tranquil state, when I suspect sulphur would be found to be disengaged in combination either with oxygen or with hydrogen gases.

* The apparatus I employed for collecting those gases which might be absorbable by water, consisted of the head of a large glass alembic, having luted to its larger aperture an iron cylinder, which admitted of being introduced into the earth at the spot from which the vapour issued.

By keeping the upper part of the glass vessel cold by the external application of ice or wet cloths, I succeeded at Vesuvius on two occasions, and likewise at the Solfatara, and at the Lipari Islands, in condensing a quantity of the steam sufficient for ascertaining the nature of the gases with which it was impregnated.

In order to determine the gases not readily absorbable in water which might issue from the orifice of the volcano, I could devise no better plan, than that of a large funnel covering the aperture, to the tube of which was attached a long flexible india-rubber tube. The latter communicated with a glass bottle having two apertures, into the upper one of which the flexible tube was inserted, whilst the lower could be opened or shut at pleasure by means of a stop-cock. The bottle being filled with water, and the funnel inserted into the fumarole, it is evident, that on opening the stop-cock the air of the funnel would be drawn into the bottle, in proportion as the water escaped.

I made trial of this apparatus at the crater of Vesuvius in October 1845, and found that the air admitted into the glass vessel was charged with carbonic acid, as it rendered lime-water immediately turbid; but not being able to meet, amongst the scoriæ and lapilli which were present in the crater, any material of a plastic and adhesive nature, by which the access of external air could be excluded from the funnel when the latter was placed over the fumarole, I regarded it a waste of time to institute any

I had reason to suspect the presence of carbonic acid, but no unexceptionable means of proving it occurred to me. I have stated that muriate of ammonia was also present in the lava of 1834, but none could be detected at that time proceeding from the crater itself.

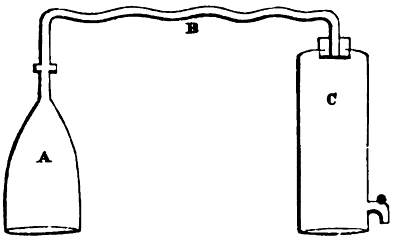
It has been asserted, that nitrogen gas is also disengaged, but I was unable to devise a mode of determining whether such was the case when I visited the crater.

Nor ought I to omit stating, that Professor Pilla has lately observed flames on three occasions issuing from the crater whilst in an active condition, from which it may be inferred, that hydrogen gas in some of its combinations ranks amongst the aëriform products of this volcano. A full discussion however of a fact so important will be best introduced, when the theory of volcanos comes under our consideration.

Besides these products however which belong to the more active states of the volcano, fatal *Moffettes*, or exhalations of noxious gases, are given out from crevices in all parts; they are frequently found in the cellars of Portici and Resina after an eruption, and, as already stated, when they rise up through the land, prove speedily destructive to vegetation. They are supposed to consist of carbonic acid, and this is undoubtedly the prevailing ingredient in their composition.

more particular examination of the air which had been collected than could be accomplished by a few hasty trials.

The following is a representation of the apparatus :—



A, Funnel; B, Caoutchouc tube; C, Bottle.

The advantage of this apparatus is, that the bottle can be filled with the gases, whilst the operator remains at a safe distance from the fumarole. But no dependence can be placed upon the results, unless the funnel be buried under some material capable of excluding the external air, except in cases where the disengagement of gas from the fumarole is going on with considerable rapidity.

CHAPTER XIII.

ISLANDS OF PROCIDA AND ISCHIA.

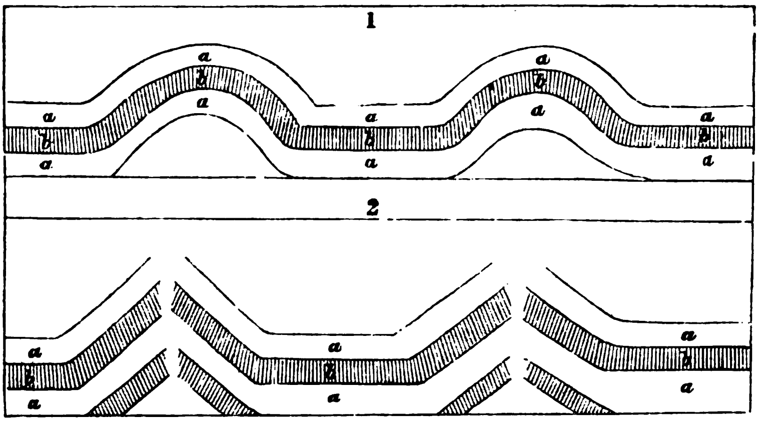
Procida—its structure.—Ischia—its tuff—trachyte—lava-streams—hot springs and vapour issuing from the rocks—eruptions in historical times.

THE neighbouring islands of Procida and Ischia are likewise composed of volcanic rocks bearing a considerable resemblance to those of the Campi Phlegrei.

The former island seems to consist entirely of tuff separated by beds of cellular lava. In one part where the coast exposes a section of the strata, I observed that they were so contorted as to represent an arch, whilst in the places intermediate, as well as on either side, they appeared horizontal.

This effect, happening as it here does in a volcanic country, seems attributable to the pressure of elastic vapours from below, which may have heaved up the strata round a given area; and it will be readily perceived, that if the force applied had been considerable enough to cause a disruption of the beds, we should then have had them dipping in all directions away from the opening, as happens where a crater is produced.

In the following sketches No. 1 represents the actual section, and No. 2 that which would have resulted had the force been somewhat greater. In either case A represents the beds of tuff, and B those slaggy lava interposed.



The island of Ischia is somewhat more varied in its composition. It is composed for the most part of a rock which seems to consist of very finely comminuted pumice, reagglutinated so as to form a tuff, sometimes resembling the Puzzolana of Naples.

From the very fine state of division however into which it was reduced at the time when it underwent consolidation, a rock has often resulted of so homogeneous a texture as to be considered a variety of felspathic lava; but I am, upon the whole, rather disposed to believe it to be a substance resulting from the reaggregation of fragments of pumice and other analogous products*.

This formation is often separated by beds consisting of loose portions of pumice and obsidian, and with this exception nearly all the island may be said to consist of tuff, which extends even to the summit of Mount Epomeo, its loftiest point, attaining a height of 2605 feet above the sea.

I could discover nothing like a crater on the summit of this hill, but conceive its superior elevation to arise merely from the rock in this locality having resisted decomposition more than it had done elsewhere.

Although the pumiceous conglomerate, as I shall venture to call this rock, is seen in every part of the island, yet at Monte Vico, near the town of Foria, we observe thrust up through the midst of it huge blocks of trachyte, sometimes thirty feet in diameter, consisting of a congeries of crystals of glassy felspar, without any thing intermediate. These blocks are angular and of irregular shape; they seem in some places scattered without any order through the substance of the tuff.

A little beyond the village of Casamicciola is a conical hill, called the Monte Thabor, composed entirely of trachyte,

* Mr. Forbes and M. Dufrenoy both agree with me in regarding the rock of Mount Epomeo as a species of tuff or conglomerate, although Brocchi and other eminent geologists considered it as an earthy variety of trachyte. It certainly bears a considerable resemblance to the rock of the Puy de Dôme, but there are on the other hand varieties of the pumiceous conglomerate of Hungary which possess in quite as great a degree the characters of a trachytic rock; and this consideration, coupled with the frequent presence of scoriform portions different in colour from the matrix, confirms me in the view I have taken of its nature.

one variety of which seems to approach to clinkstone porphyry.

This trachyte rests upon a bed of clay, sometimes red and ferruginous, at others blue, in which are imbedded several species of Arca, Murex, Turbo and Trochus, enumerated by Brocchi *, and found to be identical with those now living in the Mediterranean. Thus the date of the trachyte cannot be anterior to that of the newest members of the tertiary class of rocks.

As we proceed from thence in an easterly direction round the coast of Ischia, we meet with evidences of volcanic operations belonging to a still more recent date.

At Castiglione the ground is covered with loose fragments of pumice and obsidian, which appear to be derived from one or other of two neighbouring craters, namely Monte Rotaro and Montagnone. Still further we cross the stream of lava, called Arso, which issued from the side of Monte Rotaro in the year 1302, remarkable from the large crystals of glassy felspar which are imbedded in it. Its surface is still undecomposed and consequently barren, moss alone growing upon it, and that only in a few parts, a proof of the number of ages required for bringing some lavas † into a state fit for cultivation. This current may be readily traced up the mountain to the point from whence it issued, which is marked by the existence of a crater originating apparently from the eruption itself.

The castle of Ischia itself stands on a projecting mass of lava, which appears to have made a part of a current that may be traced to the neighbouring heights of Campignano, where it constitutes a sort of ridge resting upon the pumiceous conglomerate. Its high antiquity is evident from the changes that must have since taken place in the figure of the island; for not only has this promontory been separated from the island by some subsequent convulsion, but we immediately perceive that a stream of lava at the present time

* Conch. Subapp. p. 354.

† This lava I find very sparingly soluble in muriatic acid. I dissolved little more than ten per cent. by repeated digestion in that menstruum, whereas nearly half the weight was taken up in the case of the lavas of Vesuvius.

would pursue a very different direction, and, instead of reaching the promontory, would fill up the valleys and indentations in the coast which the present current overlooks.

Thus Ischia appears to have been subjected to volcanic action of as many different periods as the neighbourhood of Naples itself, its pumiceous conglomerate corresponding with the Puzzolana, its trachytes to the rock of the Solfatara, and the lava of the Capo d'Arso to those of Vesuvius. Even the ancients were fully aware of its volcanic nature, attributing it to the giant Typhœus being confined under the mountain; and Strabo relates that a colony sent over by Hiero, tyrant of Syracuse, was so alarmed by the frequent earthquakes, that they deserted the island*.

Not less was the consternation excited by the eruption which gave rise to the lava-stream of Arso already noticed. Thus Villani in his 'Florentine History' (lib. viii. c. 53) observes, that in the year 1302 a tremendous conflagration broke out from this crater, so that through the whole extent of the island much of the country was consumed and laid waste, and even many of the people and of the cattle in it were destroyed. Multitudes also, to escape from the danger, fled to Procida, Capri and the mainland, and remained there during the continuance of the internal commotions, which lasted more than two months.

At present the only indications of volcanic action are those afforded by the hot springs so common throughout the island.

In the year 1834 I visited almost every one of them, principally with the view of ascertaining whether, like others that had fallen within my notice elsewhere, they evolved nitrogen gas. The following were the particulars which I noted at the time respecting them:—

Near the town of Ischia are thermal springs with a temperature, the one of 122·5° Fahr., the other of 102°. They have a saline taste, and contain a few white confervæ, but no gas rises up through them.

Near Castiglione are stufes or clefts in the earth evolving steam, but no saline matter is present.

---

* Strabo, lib. v. He tells us that Ischia was torn by some convulsion of nature from the mainland, but this is not probable.

Near Casamicciola is the hot spring of Gurgitello, having a temperature of 142°, with a mawkish and peculiar, but not a saline taste. Near it is the Aqua di Cappone, where I collected from the Baths an efflorescence, which appeared to consist of sulphate of soda and a little common salt. There are likewise some stufes proceeding manifestly from the same source as the spring of Gurgitello. Under Mount Thabor are the stufes of Cayuco, issuing from the trachytic rock above noticed.

Near the sea-shore at Lacco are the warm springs of Santa Restituta, the temperature of which is 115°, and a little above are the stufes of San Lorenzo.

Near the town of Foria on the sea-shore are the hot springs of Citara, one of which has a temperature of 81° Fahr., the other one of 120°. A little further, the road on the sea-shore is extremely hot, having a temperature of 130° one foot below the surface, and emitting much steam.

In a deep ravine or water-course cut through the tuff and extending to the sea is the warm spring of Olmitello (78° of Fahr.), and in the village of Testaccio above is a dry stufe, or an evolution of hot air unaccompanied with steam.

In every one of these cases my attention was particularly directed to ascertaining whether gas was evolved from the spring, but in no one instance did this occur. I also tested the character of the saline efflorescences found near the springs, with a view of learning whether ammonia was present in them, but never succeeded in detecting any by the usual tests. I also found that the air emitted from the stufes contained its usual proportion of oxygen.

It may therefore be concluded, that these warm springs and warm vapours merely arise from the rains which fall in the island, sinking down into a rock which still retains some portion of the heat derived from antecedent volcanic operations, but not from any going on at the present time, in this respect therefore differing from the hot springs of most other localities. (See the Chapter on thermal waters.)

Where steam passes through the rock, the fissures in it are often coated with a white siliceous incrustation, which Dr. Thomson, I believe, was the first to notice under the name of *fiorite*.

Dr. Macculloch* has noticed a similar phænomenon as occurring in the graphic granite of the Isle of Rona, where the surface of the quartz, or chalcedony as it has been otherwise called, obtains from exposure to the weather a glossy enamel, arising apparently from a partial solution of the silex. A similar enamel is to be observed in-

---

* Geological Transactions, vol. ii. p. 392.

vesting the sandstones of Jura and of Schehallion, and in the granite of Rockall.

The circumstances of the case are certainly more favourable to chemical action in the vapour baths of Ischia, as the aqueous particles are presented to the silex at a high temperature, and in a minute state of division, at the moment of their deposition from the state of vapour.

I need not insist upon the analogy between the above phænomena and those presented at the Geysers in Iceland hereafter to be described, but I may remark, that similar concretions are noticed as occurring, among the volcanic rocks of the Solfatara near Naples, and of Santa Fiora in Tuscany; by Humboldt at Teneriffe; and by Von Buch in Lancerote. In these cases, the alkali, which in the Iceland Geysers is supposed to assist in dissolving the silex, does not appear to be present. The late experiments by Dr. Turner, on the power which high-pressure steam possesses to dissolve silica, may perhaps throw light upon this phænomenon.

CHAPTER XIV.

LIPARI GROUP OF ISLANDS.

Stromboli—its crater—unintermitting character of its eruptions—tuff and dykes of lava. Lipari—central portion, consists of tuff—acted on by sulphureous vapours.—Southern portion, composed of pumice and obsidian.—Northern portion the same.—Glassy lavas. Volcano—description of its crater—date of the last eruptions. Panaria described.—Basiluzzo—Salina—Felicudi—Alicudi—Ustica.

The Lipari Islands, between Naples and Sicily, are made up of a class of volcanic formations analogous to some of those we have been just considering.

Like the neighbourhood of Naples too, they afford us the means of comparing the products of active and half-extinguished volcanos, with those which have arisen from the same cause at earlier periods.

The volcanic action here seems to have been developed along two lines, the one nearly parallel to that of the Apennines, beginning with Stromboli, intersecting Panaria, Lipari and Volcano, and exhibiting traces of its prolongation on the coast of Sicily in the fumaroles which are evolved from the rocks of Cape Colara; the other extending from Panaria to Salina, Alicudi and Felicudi, and again visible in the volcanic products that make their appearance at Ustica.

The Map at the end of the volume shows the connexion between these several islands, which it is the purpose of the present chapter to describe.

Stromboli.

The island of Stromboli consists of a single conical mountain, having on its summit a circular crest of rocks broken away on one of its sides, which Hoffman* regarded as a *crater*

* Poggend. Annal. vol. xxvi. for 1832.

of elevation encircling a smaller crater, also imperfect on the side looking towards the sea, from which the present eruptions take place.

These consist of ejections, repeated at very short intervals, of stones, scoriæ and ashes, which either fall back within the crater, or are carried in one or the other direction, according to the drift of the wind. As however the active crater is placed on the slope of the precipice, and not upon its summit, the ejected matters tend but little to increase the accumulation of substances in its immediate neighbourhood, but are for the most part carried into the sea.

Hoffman, who visited the island since myself, describes three openings in the crater which gives vent to the present energy of the volcano. The largest of the three is constantly evolving aqueous vapour; the second, besides steam, is constantly discharging red-hot stones and scoriæ; the third only lava.

Placed on a favourable position for surveying the whole scene, Hoffman could distinctly perceive the molten mass rising and falling successively some twenty feet within this hollow, and the rush of air through it was manifested by the noise, which resembled the roaring of a smelting furnace when the door which confines its gaseous products is opened. At perfectly regular intervals a louder detonation was heard, followed by an escape of steam from the aperture, and by the ejection of blocks of lava to a great height. A pause would then take place, until after a short interval the same train of operations was renewed.

Similar reports are given by Mr. Scrope, by Capt. Smyth, and by Spallanzani. For my own part, it was with considerable difficulty that I reached the summit of the mountain, which rises at an angle often of nearly 40°, and is covered completely with volcanic sand, consisting of titaniferous iron, amongst which I found numerous crystals of augite, and masses of black pumice, or of a highly scoriform and fibrous description of lava which seems to approach nearly to that mineral*.

* Humboldt remarks (Pers. Narr. vol. i. p. 226) that he has seen black pumice-stones in which augite and hornblende are easily recognised; they

On looking down from that elevation upon the volcano, it appeared to me that its minor explosions were in general almost continuous, but that the greater ones, which alone were audible below, take place at intervals of about seven minutes. The latter were sufficiently terrific to give me an idea of what takes place during an eruption of Etna or Vesuvius, but as the wind did not blow the stones in our direction, we should have incurred no considerable risk in approaching it nearer. On expressing however this wish to my guides, I was reminded, by their refusing to accompany me, of the remark which Spallanzani makes in respect to the superstitious horror entertained in his time by the Liparotes of the crater of Volcano, which obliged him to procure a Calabrian for his attendant; and finding that no one would venture to accompany me nearer, I thought it prudent to abandon the attempt.

The most remarkable circumstance connected with the operations of this volcano is their regularity and uninterrupted character. I have already remarked that there is a continual recurrence of explosions, to which may be added, that from the smaller and lower of the three apertures within the crater, a small stream of lava, like a perennial fountain, is constantly issuing. It flows down the mountain in the direction of the sea, which however it never appears to reach, becoming solid before it arrives at that point. Some portions however of the congealed mass are continually detached and roll down into the water.

No cessation indeed has ever been noticed in the operations of this volcano, which is described by writers antecedent to the Christian æra in terms which would be well-adapted to its present appearances*.

are less light, of a spongy texture, and rather cellular than fibrous: we might be tempted to think that these substances owe their origin to basaltic lavas. He has observed them in the volcano of Pichincha, as well as in the tufa of Posilippo near Naples.

* Callias, a contemporary of Agathocles, who made himself absolute in Sicily from B.C. 317 to 289, is quoted by the Scholiast to Apoll. Rh. iii. 41, as mentioning the fires of Lipari, meaning probably Stromboli,

The unintermitting character of the eruptions at Stromboli appears to arise, as Mr. Scrope has suggested, from the exact proportion maintained between the expansive and repressive force. The expansive arises from the generation of a certain amount of aqueous vapour and of elastic fluids, the repressive from the pressure of the atmosphere and from the weight of the superincumbent volcanic products. In most volcanos the gradual accumulation of scoriæ and fragments of rock around the orifice increases the repressive force, until it controls for a time the expansive energy; but at Stromboli no such accumulation takes place, because the greater part of the ejected matters finds its way into the sea, where it is probably washed away by some submarine current.

Where these forces are so nicely balanced, it seems no extravagant supposition to imagine, that the degree of barometric pressure exerts, as Scrope supposes, an influence over the eruptions; and this may explain a fact remarked by the people of the island, that the volcano is most active in stormy weather, when the barometer is low. In fact, from time immemorial, the sailors have judged of the direction of the wind, by the rapidity and force with which the red-hot stones were projected into the atmosphere. The west, which is attended with a depression of the column of mercury, causes the eruptions to follow each other with rapidity, and imparts a greater brightness to the apparent flames, than takes place under the

and it is probable that Theocritus may refer to the same island, when he says—

Ερως δ'αρα και Λιπαροιο
Πολλακις Ἁφαιστοιο σελας φλογερωτερον αιθει.

As likewise Aristotle, where he states that in Lipari the fire, after a cessation of sixteen years, returned on the seventeenth. Stromboli (Στρογγυλη) is mentioned by name by Diodorus Siculus, as giving rise to explosions of air, and to ejections of sand and heated stones. The same, he says, is the case in Hiera, now Volcano. Strabo (lib. vi.) speaks of Lipari, Volcano and Stromboli as emitting flames, and says that those in the latter island are inferior to the two former in point of violence, but superior in brightness. Cornelius Severus, on the other hand, speaks of the volcano in Stromboli as greater than that of Etna :—

Fœcundior Etnâ
Insula, cui nomen facies dedit ipsa *rotundæ*.

influence of the north or east wind. "*E cujus fumo*," says Pliny, "*quinam futuri sint venti, in triduum prædicere incolæ traduntur, unde ventos Æolo paruisse, existimatum.*"

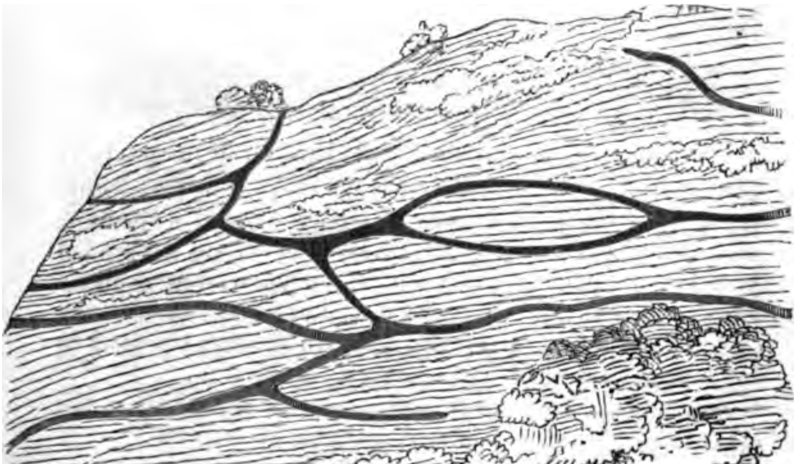
Disappointed, as I have stated, in my attempt to get close to the active volcano of Stromboli, I contented myself with visiting those parts of the island which were not in the immediate vicinity of the volcano, and found them chiefly composed of a tuff, in some places not unlike that which I have described as occurring in Ischia. In one place the cavities are lined with specular iron in very minute laminæ.

This tuff is in some places penetrated by dykes of a cellular description of rock, which approaches in its mineralogical characters to trachyte.

These dykes often pursue so regular and horizontal a course through the tuff, that they may be readily mistaken for beds alternating with that rock; but when we trace them to any distance, the deviations that occur from their original direction, and their origin from two or three roots that rise vertically from below, sufficiently betray their real nature.

Tuff penetrated by Dykes of Slaggy Lava—Stromboli.

No. 1.



Tuff penetrated by Dykes of Slaggy Lava—Stromboli.

No. 2.

Dr. Macculloch has noticed some dykes of a similar kind in his Description of the Hebrides, especially in plate 17. in which he represents several appearances produced by the interference of the trap with the secondary strata on the east coast of Trotternish.

The following is a contracted sketch of one of his drawings:—

With regard to the mineralogical character of the products of Stromboli, Abich remarks, that the rocks which constitute the walls of the ancient crater of elevation are of a trachytic character and of a reddish-grey colour. They are intersected by dykes of a light grey rock with sparkling crystals of glassy felspar, wherein greenish augite resembling diopside takes the place of hornblende, and is disseminated through the mass in conjunction with dark-coloured scales of mica.

The modern lavas and ejected masses of Stromboli on the other hand are a true dolerite, consisting of

Labradorite . . .	48·18 per cent.
Augite	44·91
Magnetic iron . .	6·91

We shall find, as we proceed, that this composition brings the lavas of Stromboli into a near connexion with those of Mount Etna.

Before concluding my account of Stromboli, I must not omit to state, that Hoffman, in the 'Bull. de la Soc. Géol. de France,' vol. iii., withdraws his assent to the elevation theory with reference to this particular island. He admits indeed, that the want of identity between the constitution of the new cone and of the ancient one favours such a view, but he alleges, as an objection to it, the absence of those deep *barancos* which are implied by such an hypothesis—the narrow gorges seen in so many places round the external slope of the island being in his opinion attributable only to water. He extends the same conclusion to Volcano, Lipari, Monte Somma, and even to Etna, but he protests against his being quoted as an authority adverse to the elevation theory in its application to other parts of the world; considering, he says, craters of elevation to be no more improbable in themselves than are craters of eruption.

Lipari.

The next island I visited was Lipari, the whole of the western portion of which, together with a strip of land in the east near its centre, where the principal town and the harbour are situated, is composed of tuff.

Both in the northern and southern part however the latter is lost sight of, and beds of pumice and blocks of obsidian heaped one above the other take its place almost entirely.

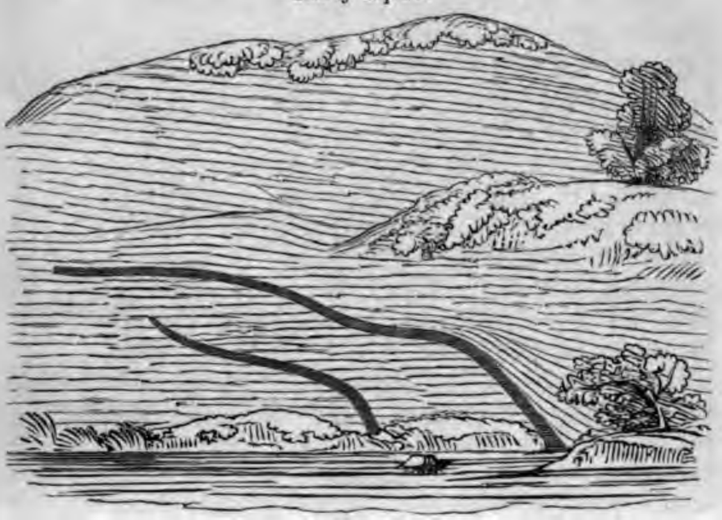
Thus the island may be conveniently divided into three districts, as has been done by Hoffman, who, since my own cursory visit to the spot, has examined its geological structure in much greater detail, and in a much more trustworthy manner.

With regard to the more centrical district, which consists of tuff, I may first record from my own observations the existence in it of dykes, similar to those described under the head of Stromboli.

These, notwithstanding their general horizontality, betray their real origin in a manner similar to that of the dykes at Stromboli, and likewise in one instance from the disturbance

they have occasioned in the direction of the beds of tuff, which are thrown up obliquely by the dyke, as is represented in the section annexed.

Section of the Tuff and Slaggy Lava in a place called Vulcanello, Isle of Lipari.



The tuff resembles that near Rome, and would seem to be of submarine origin; nevertheless Dolomieu, and since him Hoffman, have observed imbedded in it impressions of land plants belonging both to the dicotyledonous and monocotyledonous division. Amongst the latter were distinctly recognised the leaves of the *Chamærops humilis*. A similar admixture however of terrestrial with marine productions occurs in the tuff near Naples.

The highest point in the island, consisting of tuff, is the mountain of St. Angelo, 1600 feet in height, on which Hoffman discovered a crater very little altered by time. Another also exists on the side of a promontory called the Monte Rosso. Two streams of lava have flowed from the first-mentioned crater, which have a very felspathic character, and are called by him porphyritic lavas.

A continuance of this same volcanic action at the present day is manifested by the hot springs and stufes or vapour-baths of San Calogero, situated about four miles from the

town of Lipari, which I visited in 1824. It is not improbable therefore that Lipari may have had an active volcano even within the historical period, and it is to be remarked that the ancients speak of this island as emitting a fiercer fire than Stromboli*.

Strabo indeed particularly mentions an eruption of mud, attended with smoke and flame, which took place in the sea between Hiera (the island of Volcano, near Lipari) and Euonymos, which, as above stated, was probably either one of the islands between Stromboli and Lipari, or comprehended the whole of that cluster of intervening rocks†.

Before this occurred, the sea between these two islands rose to an unusual height, and became so warm, that the fish died in numbers sufficient to taint the air ‡. Strabo indeed adds, that flames have been observed rising from the sea in the neighbourhood of those islands, and Pliny notices the same as happening for several days during the Social War §.

Homer seems to allude to something of the same kind in the 12th book of the Odyssey, where Circe relates to Ulysses the dangers he is to undergo near the coast of Sicily ‖; and even the epithet of "floating" (*πλωτη*), which he has applied to the island in which king Eolus reigned, may be supposed to refer to the earthquakes¶ with which the country was agi-

* *Την δε Λιπαραν και την Θερμισσαν ειρηκαμεν· ἡ δε Στρογγυλη, καλειται μεν απο του σχηματος, εστι δε και αυτη διαπυρος, βιᾳ μεν φλογος λειπομενη, τῳ δε φεγγει πλεονεκτουσα.* (Strabo, lib. vi.)

† May not the comparatively recent origin of the Isle of Lipari be inferred from the sterility ascribed by Cicero to the country (see Orat. iii. in Verrem)? for as it is at present very fertile, its barrenness may have arisen from the circumstance, that sufficient time had not elapsed to cause a suitable decomposition of the masses ejected.

‡ Julius Obsequens, who evidently alludes to the same event, places it in the consulship of Æmilius Lepidus and Aurelius Orestes, or 125 years before Christ.

§ Near a century before Christ.

‖ Especially in the following lines:—

> *Αλλα θ' ὁμου πινακας τε νεων και σωματα φωτων*
> *Κυμαθ' ἁλος φορευσι, πυρος τ' ολοοιο θυελλαι.* M. 68.

¶ *Αιολιην δ' ες νησον αφικομεθ'; ενθα δ' εναιεν*
> *Αιολος Ἱπποταδης, φιλος αθανατοισι θεοισι*
> *Πλωτῃ ενι νησῳ.* K. 3.

tated at a time when the volcanic operations were in greater activity.

This may seem far-fetched in a country like our own, happily but little subject to these convulsions of nature; but to an American it might appear an obvious allusion, as Humboldt remarks, that on the coast of Peru earthquakes are so frequent, that we become as much accustomed to the undulations of the ground, as the sailor is to the tossings of his ship caused by the motion of the waves *.

It is remarkable how throughout the whole valley the rocks are whitened and otherwise altered by the sulphureous exhalations, as in the immediate neighbourhood of the Baths, indicating that at a former period the gases were evolved much more copiously, and from a larger number of vents.

Hoffman particularly notices the interesting veins of gypsum which here intersect the rock, manifestly derived from the action of sulphureous vapours upon the calcareous matter present in it, and thus highly illustrative of the origin of gypseous veins in other situations. I shall return to this subject when speaking of the sulphur beds in Sicily.

In the southern portion of the island, pumice and obsidian, as has been stated, take the place of tuff. Almost the whole of that district consists of a single mountain, called Monte Guardia, about 1200 feet above the sea, on which, nearly 600

* From our infancy the idea of certain contrasts fixes itself in our minds; water appears to us an element that moves; earth, a motionless and inert mass. These ideas are the effect of daily experience; they are connected with everything that is transmitted to us by the senses. When a shock is felt, when the earth is shaken on its old foundations which we had deemed so stable, one instant is sufficient to destroy long illusions. It is like awakening from a dream; but a painful awakening. We feel that we have been deceived by the apparent calm of nature; we become attentive to the least noise; we mistrust for the first time a soil on which we had so long placed our feet with confidence. If the shocks be repeated, if they become frequent during successive days, the uncertainty quickly disappears. In 1784 the inhabitants of Mexico were as much accustomed to hear the thunder roll beneath their feet, as we are to recognise it in the region of the clouds. Confidence easily springs up in the human breast, and we end by accustoming ourselves on the coast of Peru to the undulations of the ground, like the sailors to the tossings of the ship caused by the motion of the waves. (Humboldt's Pers. Narrative, vol. iii. p. 321.)

feet below the summit, are vestiges of a crater. Here we observe one of those lava-streams which are so peculiar to Lipari, the whole of which is a glass of a pale grey colour, diversified with a few dull-grey, or more rarely reddish streaks, and resembling pumice in the number and elongated shape of its pores, although greatly exceeding it in point of compactness. The direction of its numerous pores imparts to the rock in general a fibrous character, and the fibres run in the direction in which the stream flowed. Layers of obsidian are seen here and there interstratified with the mass. The *coulée* is of great magnitude, attaining, on the summit of the Monte Guardia, from which it appears to have issued, a thickness of 300 or 400 feet.

Another remarkable lava-stream is like a compact claystone, and is divided into tabular masses; yet even this in some places passes into pumice, showing that the material from which it had been derived was of the same nature.

Great accumulations of pumice are to be seen in this part of the island, but it is in the north that the above mineral is seen in a state of the greatest development. It is from the latter quarter that all Europe has from time immemorial been supplied with this material. There are here two mountains, called Monte di Tre Pecore and Campo Bianco, both lofty, and alike composed of beds of white pumice and of blocks of obsidian, which succeed each other with the greatest regularity.

On the summit of Campo Bianco Hoffman discovered a perfect crater half a mile in diameter and 500 feet deep, and in its interior a stream of lava of a pumiceous character, as fresh as if it had been just emitted from the earth, was observed. It has a curious veined structure, its striæ being parallel to the direction of the stream, and it splits into tabular masses two inches in thickness and a foot square.

The crater of Campo Bianco seems at one time to have been encircled by one much larger and loftier, which is now in part broken away, just as we remarked to be the case at Stromboli.

Dolomieu observes, that the pumice of this part of the island seems to be derived from the fusion of granite; for not only did he observe in the midst of this substance fragments con-

sisting of quartz, mica and felspar, but when such fragments had been exposed to heat, they were converted into a substance resembling in its general characters the pumice surrounding it.

The presence of fragments of granite in obsidian has also been remarked by Hoffman; and as the trachyte, out of which both this mineral and pumice are produced, presents the first stage of alteration from granite, the conjecture of Dolomieu may still be admitted as probable.

With regard to the obsidian, some of its varieties possess a remarkable resemblance to certain products obtained by Mr. Gregory Watt* during the cooling of large quantities of basalt, an incipient crystallization beginning to manifest itself in the midst of the vitreous mass in the appearance of white or lighter-coloured spots, which appear to be made up of points radiating from a common centre.

In many of the Lipari obsidians, however, these round spots are composed of concentric laminæ, and are disposed in general in lines, so as to give a resemblance of stratification to the mass. In other cases the whole mass is made up of globules of this kind, which are hollow internally, and are sometimes cemented by black obsidian.

The obsidian also occurs in a brecciated form, large angular masses of it being held together by a white earthy-looking paste, which is hard and gritty, whilst in other cases this paste has all the appearance of a white enamel, such as is used for china or pottery.

The most remarkable circumstance however concerning these obsidians is the mode in which they occur, not only, as one might expect, in the form of loose ejected masses, which from the great relative extent of their surface to the internal mass were soon cooled in the atmosphere, and therefore put on a vitreous form, but constituting actual lava-streams, which ought, it should seem, to have been subjected to the same laws of congelation as the lavas of other volcanos.

One of these I observed on my way from the town of Lipari to Monte di Campo Bianco, at the village of Canneto, near the shore, and others are noticed by Hoffman; so that we must attribute their vitreous character to some peculiarity in

* See Phil. Trans. for 1804.

the chemical constitution of the material, and not merely to the rapidity with which it had passed into a solid condition after having been fused.

The best observations on this subject are probably those of Abich in the memoir to which I have referred in my second chapter, but, as the author himself admits, they do not meet the whole difficulty of the case; for although it may be true that glassy lavas can only result from trachytic materials, yet it still remains to be shown why trachyte has not given rise to streams of obsidian in other neighbouring localities as well as in Lipari.

Hoffman is of opinion that the pumice and obsidian are both more modern than the tuff. They occur indeed in the latter, but only in its upper beds, and are for the most part scattered over its surface. Thus, after Monte St. Angelo and its vicinity had been heaved up from the bottom of the sea, a different kind of volcanic energy appears to have taken place, and thus to have given birth to the Monte Guardia in the south, and to the Campo Bianco and Monte di Tre Pecore in the north of the island, which are composed of vitreous products.

Vulcano.

Separated from Lipari only by a narrow channel is the little island of Vulcano, which at a period antecedent to the Christian æra appears to have been in a state of activity at least equal to that of Stromboli*, and still emits gaseous exhalations from the interior, as well as from several parts of the external surface, of a crater situated on the highest part of the island.

These vapours, acting upon the rock they penetrate, decompose it, and form with its constituents large quantities of alum and other sulphuric salts.

* The old chronicles would lead us to suppose that the last indication of volcanic agency in Lipari took place about the sixth century, for we are told that St. Calogero, the patron of the island, put to flight the devils, which, like the Typhon of old, inhabited the recesses of the island, and that the latter first took refuge under the mountain from whence the warm springs issue, but being driven from thence repaired to Vulcanello, and finally were chased into the crater of Vulcano. Later writers always speak of the flames of Lipari as extinct. See Dolomieu sur les Iles de Lipari, p. 71.

The process appeared to be somewhat different from that which takes place at the Solfatara, since the vapour *here* consists of sulphurous acid, *there* of sulphuretted hydrogen, as I ascertained by procuring portions of the condensed vapour from either source.

The ultimate result however in both instances is the same, the compounds arising from the union of this acid with the earths contained in the rock with which it comes into contact, being all ultimately resolved into sulphuric salts.

There is one product however that seems peculiar to this volcano, or at least has not been found belonging to any other in the south of Italy. I mean the boracic acid, which lines the sides of the cavities in beautiful white silky crystals, and occurs also, it is said, combined with ammonia.

Ammonia is likewise found united with muriatic acid, or in the form of sal ammoniac; its production I have attempted to explain when speaking of it as occurring under similar circumstances at the Solfatara.

In a mixture of this salt with sulphur, Stromeyer detected the presence of selenium *. It is probably sublimed in combination with hydrogen, just as the sulphur and the arsenic which sometimes accompanies that mineral are supposed to be.

The operations of this volcano appear to be going on with much greater vigour than those of the Solfatara, and exhibit perhaps the nearest approximation to a state of activity, during which a descent into the crater would have been at all practicable.

Nor can I imagine a spectacle of more solemn grandeur than that presented in its interior, or conceive a spot better calculated to excite in a superstitious age that religious awe, which caused the island to be considered sacred to Vulcan, and the various caverns below as the peculiar residence of the god.

> Quam subter, specus, et Cyclopum exesa caminis
> Antra Etnea tonant, validique incudibus ictus
> Auditi referunt gemitum, striduntque cavernis
> Stricturæ Chalybum, et fornacibus ignis anhelat:
> Vulcani domus et Vulcania nomine tellus.—*Virg. Æneid.* viii. 418.

* See, for a full account of this discovery, the Göttingen Gelehrte Anzeigen for February 1825. The English journals contain an abridgement.

To me, I confess, the united effect of the silence and solitude of the spot, the depth of the internal cavity, its precipitous and overhanging sides, and the dense sulphureous smoke, which issuing from all the crevices throws a gloom over every object, proved more impressive than the view of the reiterated explosions of Stromboli, contemplated from a distance and in open day.

The last eruption which the volcano has experienced appears to have happened in the year 1786, when after frequent subterranean noises and earthquake shocks, the crater vomited forth during fifteen days showers of sand, together with clouds of smoke and even flame, altering materially the shape of the crater from which they proceeded*. No lava-stream was

* If the Biography of St. Willebald, which makes a part of that extraordinary Collection published by members of the Littlemore School a year or two ago under the title of the 'Lives of the Saints,' be not altogether fabulous, we may collect from the following passage in it, that the volcano was more active sometime between the years 701 and 786, the period during which the Saint is stated to have lived, than it is at present:—

"From Reggio St. Willebald sailed to see Vulcano, one of the Lipari islands, then in a state of eruption. The Saint wished to obtain a view of the boiling crater, called the '*infernum of Theodoric,*' but they could not climb the mountain from the depth of the ashes and scoriæ. So they contented themselves with a view of the flames, as they rose with a roaring like thunder, and the vast column of smoke ascending from the pit.

"Modern geologists examine these phænomena with a cool unconcern, and lecture upon the lava; they draw no solemn thoughts from the awful spectacles of nature—that well is too deep for their superficial minds to draw from: saints have deeper feelings and less idle curiosity."

One cannot, by-the-by, help being amused at the coolness with which the editor or compiler of this strange publication assumes, as a fact not requiring proof, that geologists, as such, are unimpressed with the grandeur of the scenes which they are led to contemplate—indisposed to look up to the Great Being from whom descends that golden chain, some of the lower links of which it is their business to trace out.

As if, forsooth, there were any necessary connexion between a feeling for the beauties of Nature, and a yearning after those fables and puerilities by which Superstition has sought to disfigure her fair proportions—as if the hidden operations of a volcano were calculated to inspire deeper awe and more holy aspirations, when imagined to proceed from the gambols and freaks of imps imprisoned within the recesses of the mountain, and venting their spite upon the unfortunate Theodoric, than when attributed to the

emitted at that time, but Dolomieu states that in 1775 one of a vitreous character, now observed on the north-west slope of the crater, proceeded from the mountain. The rock composing the latter is trachytic, and encircling its present crater is a larger one, broken away on the side fronting Lipari, which may be considered perhaps the ancient crater of elevation within which the existing one was subsequently thrown up.

Close to Vulcano is an isolated rock called Vulcanello, which, though without a crater, emits from its crevices vapours of a sulphureous nature, a feeble remnant of the volcanic action by which it was formerly itself thrown up from the bosom of the sea. It is probable, at least, that it is to this event that Aristotle* refers, when he states that in the island of Vulcano part of the ground swelled up, and rose with a noise into the form of a hillock, which burst and gave vent to a great quantity of air, carrying along with it flame and ashes, the latter in sufficient quantity to cover all the town of Lipari.

The time at which this event happened seems to be fixed by other writers, for Pliny † mentions an island which emerged

workings of those mysterious forces which God himself has from the beginning implanted in matter to accomplish his divine purposes!

Fortunately for the author of this work, the writers in question are unlikely in the year 1847 to retain their authority, even if they ever possessed any, over his English readers or indeed over any who are *bonâ fide* members of a Protestant establishment.

They have now for the most part migrated into an atmosphere more congenial, it is to be hoped, to their spiritual constitution, than that of their own Mother Church, although, if I mistake not, they will have already found, to their no small discomfiture, that in an inquiring age, and under a liberal pontiff, the very priests of the communion they have joined no longer care to conceal their anxiety to get rid, so far as they are able, of that cumbrous legacy of fable and imposture which the ignorance and fraud of preceding ages have entailed upon their creed—excrescences however, which seem to be regarded by these recent proselytes with more fondness, in direct proportion to their grossness and extravagance:—

"Uti Balbinum polypus Agnæ."

* Vide Aristot. περι Μετεωρων, lib. ii. c. 8.

† "Ante nos et juxta Italiam inter Æolias insulas, item juxta Cretam emersit e mari M.M.D. passuum cum calidis fontibus, altera Olympiadis CLXIII. anno tertio in Tusco sinu; flagrans hæc violento cum flatu." —*Pliny*, lib. ii. c. 87.

from the sea among the Lipari islands in the 144th Olympiad, or about 200 years before Christ, whilst Orosius fixes the event as happening in the consulship of Marcellus and Labeo, which answers to the year 182 B.C.*

Whichever of these dates be preferred, it is equally clear that the island now called Vulcano cannot have been referred to, for Thucydides, who flourished at least 400 years before Christ, mentions Hiera (Vulcano) as being *cultivated*, which implies that a certain time had elapsed since its production†. It is probable therefore, that the rock which Aristotle states as having been thrown up from the sea was that now called Vulcanello, which lies at a short distance from Vulcano.

South of Stromboli, and intermediate between it and the island of Lipari, are several rocks and small islets, which Dolomieu conjectured to be the parts of a large submerged island, six miles in diameter, which existed in the time of Strabo under the name of Euonymos.

The largest of these is the island of Panaria, next in size Basiluzzo, and the others mere rocks, namely Dattolo, Lisca Nera, and Lisca Bianca. The latter is regarded by Cluverius as the Euonymos of the ancients, whilst according to the view taken by Dolomieu, it would constitute only a part of what was once that island.

Hoffman however is disposed to consider these rocks and islets as the protruding points of a great submarine tract which has been elevated above the waters, taking just the contrary view of their origin from that adopted by preceding writers.

Panaria, according to this latter geologist, consists altogether of a description of trachyte resembling some of the clay porphyries found in older secondary formations, but

* Orosius, lib. iv. c. 20.

† Και οἱ μεν εν Σικελιᾳ Αθηναιοι και ῾Ρηγινοι, του αυτου χειμωνος, τριακοντα ναυσι στρατευουσιν επι τας Αιολου νησους καλουμενους. νεμονται δε Λιπαραιοι αυτας, Κνιδιων αποικοι οντες, οικουσι δ᾽εν μιᾳ των νησων ου μεγαλῃ, καλειται δε Λιπαρα. τας δε αλλας εκ ταυτης ὁρμωμενοι γεωργουσι, Διδυμην, και Στρογγυλην, και ῾Ιεραν. νομιζουσι δε οἱ εκεινῃ ανθρωποι, εν τῃ ῾Ιερᾳ ὡς ῾Ηφαιστος χαλκευει, ὁτι την νυκτα φαινεται πυρ αναδιδουσα πολυ, και την ἡμεραν καπνον. —(Thuc. lib. iii. c. 88.)

sometimes passing into pitchstone. It is particularly described by Abich*.

Basiluzzo consists of a rock so like to granite, that both Dolomieu and Spallanzani have set it down as such. It is however, by Hoffman's account, a singular variety of trachyte, the basis being an impure felspar containing numerous snow-white crystals of glassy felspar, and numerous scales of mica. The resemblance to granite is occasioned by the presence of grains of a vitreous mineral much resembling quartz, though less hard, which form parallel striæ in the mass.

Another variety of trachyte which also puts on the appearance of granite is of a light grey colour and granular texture, in which glassy felspar is the predominant constituent, but differing from the ordinary kind in being traversed by a number of fine pores of an oblong shape, so as to impart a fibrous or striated appearance to the mass. Black mica and grains of the same vitreous substance which occurs in the other variety are likewise diffused through it.

Abich regards this rock as a species of trachytic porphyry with a per-centage of silica amounting to 69·87, and points out the remarkable passage of so slaty and friable a material as this into a true pumice in the upper parts of the rock where the pressure was least.

North-west of Lipari are three other volcanic islands, namely Salina, Felicudi and Alicudi.

Salina is, next to Lipari, the most important of the group, and comprehends two very lofty mountains rising to a height of not less than 3500 feet above the sea. The lower portion of the island is composed of tuff, but the upper of numerous alternations of this deposit with beds of lava containing much augite. On the summit are the remains of a crater. Pumiceous conglomerate makes its appearance in one part of the island, but it is unaccompanied by obsidian.

Felicudi, according to Gussone, as quoted by Hoffman, resembles very nearly in its constitution Salina, consisting of alternating beds of tuff and trachytic lava. Sulphureous vapours still rise from crevices in one part of the island.

* Ueber die Zusammenhang der vulk. Bild. p. 31.

Alicudi is a single conical mountain with traces of a crater on its summit. Here lava predominates over tuff, and one kind approaches nearly to clinkstone.

Ustica, which lies about forty miles north-west of Palermo, contains three large craters, broken away on the side of the sea, and constituted in a similar manner to the foregoing islands, namely a brown loose tuff, and thick beds of trachytic lava full of felspar and augite, and sometimes containing olivine. Pumice is also abundant in many parts of the island.

Marine shells are found in one place imbedded in the tuff, and in certain spots the latter is impacted together by a calcareous matter, so as to form a breccia of great hardness, in which the same shells occur as exist in the Mediterranean at the present time. It seems therefore to follow that this island has been heaved up from the bottom of the sea at a very recent period.

CHAPTER XV.

VOLCANIC ROCKS OF SICILY, &c.

Sulphur beds.—Mud volcano of Macaluba.—Lago Naftia.—Older volcanic rocks of the Val di Noto.—Mount Etna—description of the volcano—long succession of lava beds and tuff accumulated one above the other—mode in which the mountain was formed—description of its crater. History of its eruptions—antecedent to the Christian æra—subsequent to that epoch. Volcanic energy exerted in the neighbouring parts of the Mediterranean—inferred from the phænomena of the Marobia and sea-quakes experienced off the coast—also by the elevation of a new island off the coast of Sciacca.—Products of Mount Etna. Island of Pantellaria—three kinds of igneous formations.

The Lipari islands are so placed with reference to Naples and Sicily, that they seem to form a link between the two countries, whence some have inferred that a subterranean communication passes through them, extending from Etna to Vesuvius. It would be necessary however to show, in a more satisfactory manner than has hitherto been done, that the condition of any one of these volcanos is influenced by that of the rest, before we venture to adopt such an opinion*; at present I shall content myself with pointing out by a detail of the structure of Sicily, so far as the latter is connected with the present subject, what degree of resemblance may subsist between the volcanic phænomena of that island and those of Naples†.

Nearly all the central portion of Sicily is occupied by a vast deposit of blue clay or marl, in which are contained numerous and thick beds, of selenite and gypsum, of common salt, of sulphur, of combinations of that mineral with iron and copper, and of the sulphuric acid with most of the earthy bases. The crystals of sulphate of strontian found in the sulphur mines are unrivalled for their beauty; and are inter-

* See the chronological table of the eruptions of Etna and Vesuvius, appended to this chapter.

† See, for a more detailed account of the geology of Sicily, my memoir inserted in Jameson's Journal, vol. xiii.

mixed with those of sulphur, which occur also lining the fissures, often in large and regular octahedra. The latter mineral is always of a bright yellow, and never of that liver colour which is met with in some other localities, a distinction worth attending to, as Brocchi* conceives that all sulphurs of the former description have undergone sublimation. Sulphate of lime occurs lining the fissures in beautiful and regular crystals, but when met with in beds, it is frequently found in large transparent plates, nearly a foot in length, and six or eight inches in breadth, which seem to be the result of an irregular crystallization.

This blue clay deposit is associated with beds of white calcareous marl, and of a calcareous conglomerate which becomes more abundant as we proceed south, and is there accompanied likewise with beds of limestone not possessing any brecciated structure.

The formation alluded to contains, it may be remarked, all the substances at present sublimed from volcanos in activity. The sulphur, the various sulphuric salts, the muriate of soda, are products found equally at Etna, at Vesuvius, and at the Solfatara, so as to lead to the inference, that they have been generated, in this instance, by submarine volcanic exhalations.

This too would account for the absence of shells, so common among tertiary rocks in general; for we know, from the case of the Lago di Solfatara near Rome, that molluscous animals will not live in sulphureous springs.

Under the head of Lipari, and when speaking of the Lake Amsanctus, I have pointed out that processes are going on at the present time, the same in kind, although inferior in degree, to those which appear to have been instrumental in producing this vast formation in Sicily.

With respect to its age I spoke somewhat doubtfully in my first edition, there being no shells whereby to identify it; even then however I inclined to the opinion of its being tertiary†, and in this I am now confirmed, by finding that Mr. Lyell is also disposed to regard it in the same light.

* Conchiol. Subapp. p. 67.

† Nevertheless I ought to mention, that M. Hoffman, Geogn. Beob. p. 115, asserts its secondary age, stating that near Girgenti beds of shelly limestone occur interstratified with it, in which he discovered the Hippurite.

There is one phænomenon connected with the natural history of the blue clay formation, which appears to be of pretty common occurrence, for it has been observed in several parts of Sicily, and likewise in the analogous rock that exists at the foot of the Apennines*. From its supposed resemblance to the eruption of a burning mountain, it has obtained the name of a Mud or Air Volcano, though perhaps it has no more right to such a title than the class of products called pseudo-volcanic have to an appellation, which assumes a connection between their products and those of the eruptions of a genuine volcano. I examined the most remarkable case of this kind, which occurs at the hill of Macaluba†, near Girgenti, in a country fully charged with sulphur and other inflammable minerals. Having reached the summit of the hill, I found the surface covered with dry clay, in which were a number of small cavities filled with water, somewhat above the natural temperature, and this was mixed with mud and bitumen, disengaging from time to time bubbles of air, which I ascertained to consist of carbonic acid and carburetted hydrogen gases. These little craters, when I visited the spot, were in a state of comparative quiescence, but it seems that at times the process goes on with considerable energy, for the mud has been known to be thrown up to the height of 200 feet, accompanied with a strong odour of sulphur.

I cannot help imagining, that the whole of these phænomena may be explained by that slow combustion of beds of sulphur, which is fully ascertained to be going on in many parts of the blue clay formation.

It is not long since the proprietor of some land in the interior congratulated himself on his good fortune, in being able to collect a large supply of sulphur already purified, by merely placing vessels to receive a stream of that substance which was constantly issuing from the side of a hill. This was occasioned by a bed of sulphur in the interior of the mountain having caught fire, the heat generated by the combustion of one portion serving to melt the remainder: nature having, in this instance, adopted the wasteful process employed from time immemorial by the Sicilians for getting rid of the intermixed clay, which consists simply in collecting the materials

* As near Modena.

† Plato, in his Phædon, probably alludes to this place when he speaks of "the torrent of mud which is in Sicily." Ferr. C. Phleg. 47. Von Hoff points out a curious analogy of name between this spot and one near the Dead Sea, where a similar phænomenon takes place, and which is called Ardh al Maclubah (Gesch. der Verand. p. 247).

into large heaps, and setting fire to them on the surface, thus causing the liquefaction of one portion by the combustion of another.

The sulphurous acid resulting from this process being retained by the moisture of the rock, and gradually converted into sulphuric acid, would act upon the calcareous particles, and give rise to the extrication of carbonic acid gas, whilst, if any bituminous matters were present, the heat generated might cause a slow decomposition, and resolve them into petroleum and carburetted hydrogen.

A continued stream of gas passing through the rock would soon establish for itself a regular communication with the surface, and the same channel, when once formed, would afford the readiest means of escape for any water, which, from its existing at a higher level on the adjacent hills, might have a tendency to make its way upwards.

This water would carry with it the petroleum which resulted from the distillation of the bituminous matter, and would fill, in the manner which we now observe it to do, the little crater-shaped cavities caused originally by the escape of the gases.

In short, the rise of the water to the summit of the argillaceous hill of Macaluba seems to depend upon precisely the same principles as the common rise of springs, when we bore through a bed of clay, and penetrate into a porous stratum underneath, saturated with humidity, and having its outgoings at a higher level than that of the upper surface of the aperture. In the case of the hill of Macaluba, the escape of aëriform fluids has done what art effects in the case of a well, and the position of its summit, overtopped as it is by the adjacent eminences, is such, that we may without difficulty suppose the relative height of the springs in that neighbourhood to be such as my hypothesis requires.

Similar phænomena occur also at Terrapilata near Caltanisetta*, and at Misterbianco near Catania, and I should be disposed to view in the same light the extrications of unrespirable gas and of petroleum which proceed from a lake near Palagonia, about twenty miles west of Catania. This lake is situated in the midst of volcanic rocks, but the latter are not derived from modern eruptions, or accompanied, in their immediate neighbourhood at least, by any other indications of present volcanic action.

The gases given out from this lake appear, from Ferrara's report†, to be principally carbonic acid and carburetted hydrogen, which are the same as those of Macaluba; and when I visited the place, the water was in a state of violent ebullition in several places, but espe-

---

* See Bulletin des Sciences for August 1825, p. 406.

† Ferrara, Memoria sopra il Lago Naftia. Palermo, 1805.

cially from two spots near the centre of the pool. The smell of naphtha, from which it derives its name of Lago Naftia, is perceived at a great distance, and this substance is seen floating on the surface. As at the Lacus Amsanctus, the gas given out proves speedily fatal to animals that are thrown into the lake; but since its great specific gravity prevents its rising to a height of more than three feet, it is possible not only to stand on its borders, but even to approach the spots from whence the disengagement of gas is taking place with the greatest vehemence.

The singular qualities possessed by the exhalations given out from this spot rendered it at a very early period an object of popular veneration, and we may perhaps recognize in the fable attached to it some traces of its volcanic origin. It was called the Fons, or Stagnum Palicorum, from two sons of Jupiter by the nymph Thalia, the daughter of Vulcan*, who was concealed by the god from the vengeance of Juno by being buried under ground, so that when the time of her delivery was come, the earth opened and brought into the world her two children, hence called Palici (*απο του παλιν ικεσθαι*) because they returned into the world after being buried under it. This fable may perhaps allude to the first origin of the gaseous emanations from two apertures, whilst the worship paid to these deities, the human sacrifices at first offered up, the temple built on the spot, and the oracle that was consulted in the sanctuary, show the fear which had been inspired by the noxious qualities of the vapour exhaled.

The description given by Ovid† of the Stagnum Palicorum so well corresponds with the Lago Naftia near Palagonia, that it seems most probable that he refers to this very spot, though Virgil fixes the former rather nearer to the river Simethus than is consistent with its actual position‡.

South of Alicata we lose sight of the blue clay with sulphur and gypsum, and find ourselves upon a rock of a calcareous nature, belonging to a series which Mr. Lyell has shown to constitute a part of his newer pliocene series of rocks.

* See Diodorus Siculus, lib. xi. Stephanus in Epit. of Servius, note on Æneid, ix. 585, &c.

† Perque lacus altos et olentia sulfure fertur
Stagna Palicorum, ruptâ ferventia terrâ.
Metamorph. lib. v.

‡ Eductum Matris luco, Symæthia circum
Flumina, pinguis ubi et placabilis ara Palici.
Æneid. lib. ix. v. 584.

This limestone rock is however the highest in the series, and is underlaid by a calcareous and arenaceous slate supported by a blue clay, concerning the age of which there can be no doubt, as, unlike the formation above-described, it contains abundance of shells, all of which, with three exceptions, M. Deshayes was able to identify with recent species. The order of superposition is observed in the centre of the island at Castrogiovanni, where the limestone formation, with its subjacent strata, rises to the height of 3000 feet above the level of the sea, as was first pointed out by myself in my Memoir on Sicily. This limestone is sometimes homogeneous in structure, at other times made up of calcareous pebbles imbedded in a matrix of the same composition. It continues as far as Cape Passero, the most southern point of the island, where it is seen to rest upon a volcanic tuff containing fragments of a cellular lava.

It became therefore of great importance to determine by its petrifactions the age of this limestone. At Cape Passero the calcareous rock contains madrepores, nummulites, melonites, cypreæ, and that curious fossil called the hippurite, which has been described in an early volume of the Geological Transactions*.

This should seem to show, that at the further extremity of Sicily, calcareous rocks of the age of the chalk have been upheaved†, for the hippurite limestone of the Morea and of Asia Minor is regarded as of this age; but throughout the greater part of the Val di Noto the limestone beds are decidedly of much more recent origin, nearly all the shells and zoophytes they contain being referable, according to Mr. Lyell, to species now inhabiting the contiguous seas‡.

With regard to the volcanic rocks interstratified, they appear to partake of that intermediate character which has been pointed out as belonging to those of Hungary and some parts of Germany. They consist either of volcanic tuff or of basalt,

* vol. ii. first series.

† Such was the opinion expressed by myself in my Memoir on Sicily and in the first edition of this book, although Hoffman, who adopts it, erroneously attributes to me the very reverse.

‡ For a full account of the Neptunian and igneous rocks of the Val di Noto, see F. Hoffman, Geognost. Beob., Berlin 1839. The shells are determined by the eminent conchologist Philippi.

the former not very distinguishable from that of Lipari and Naples, the latter generally as compact as that of the trap formations of secondary districts, and containing like them, according to Rose, water, an important observation, as tending to distinguish them from the modern lavas of Etna. Sometimes however they not only present an amygdaloidal structure, but are also observed full of hollow cells, which appear never to have contained any crystalline matter.

In short, with the single exception of Cape Passero, which appears to belong to the Apennine limestone, the rocks of the Val di Noto, whether Neptunian or igneous, may be referred to causes acting at nearly the same period, and under similar circumstances, with those to which I have already ventured to attribute the rocks of Hungary, Styria, and the Vicentin.

It is almost needless to remark, that in a volcanic formation of such an age no craters can exist, although I found such described by recent and respectable authorities. I purposely visited the Monte Vennera, south of Lentini, where there are said to be traces of a crater, and was rewarded, not by the discovery of what I was in search, but by the opportunity which my excursion gave me of obtaining a good section of the volcanic and calcareous strata between that spot and Lentini.

From the ancient volcanic rocks, let us now proceed to an examination of the more modern. Although the greater part of the country included within the circumference of Mount Etna would appear to belong to a comparatively recent epoch, yet there are some rocks in its vicinity that were probably formed antecedently to the mountain at whose foot they lie. I allude particularly to the Cyclopean Islands, with which every classical reader is acquainted, as the rocks which Polyphemus is described by Homer as hurling against the bark in which Ulysses and his crew were taking their flight. These, though now detached, must at one period have formed a connected stratum, for they are covered with a bed of marl, which seems evidently to have been continuous from the one to the other of these islands. This circumstance, and their general compactness, prove that the formation of these beds took place under the surface of water.

The same remark will probably apply to the rock of Castello

d'Aci, on the coast near Catania. It consists of a volcanic breccia, the cementing substance of a sandy nature; the nodules, a cellular kind of lava. The latter however are not rounded masses, but result from a sort of irregular crystallization, most of them possessing a radiated structure, so that they resemble a cluster of prisms meeting in a common centre. The above stellular arrangement is the most common, but in other cases the prisms have more of a fan-shaped structure; and in both instances, the point towards which they converge, as well as the interstices between them, consist of tuff.

Nothing of this kind is indicated by the structure of Etna. This mighty and imposing mountain, which, according to the accurate measurements of Captain Smyth and Sir John Herschel, rises in solitary grandeur to a height not far short of 11,000 feet*, embraces a circumference of eighty-seven miles, and is divided into three distinct regions, representing three climates as opposite as those of the torrid, the temperate, and the frigid zones.

The lower of these regions, called the fertile or cultivated, extends from the base of the mountain to the height perhaps of 2500 feet, and is covered with orchards, vineyards, and cornfields, of the most productive character.

The second, called the woody, constitutes a girdle of forest trees, investing the flanks of the volcano to a height of 6279 feet, where it is succeeded by a rugged and naked region extending to the summit, which goes by the name of the desert or barren, distinguished by a circle of snow, from the centre of which the great crater rears its majestic head.

The whole of this immense formation seems to be composed entirely either of lavas or of ejected masses, for the most part of igneous origin, which, whatever subordinate differences may exist between them, all possess the appearance of having been thrown out above the surface of water, and not under pressure.

In the structure of this mountain, everything wears alike the character of vastness. The products of the eruptions of Vesuvius may be said almost to sink into insignificance when

* The Pillar of Heaven (*κιων ουρανιη*) as Pindar calls it.

compared with its *coulées*, some of which* are four or five miles in breadth, fifteen in length, and from 50 to 100 feet in thickness, and the changes made on the coast by them are so considerable, that the natural boundaries between the sea and land would seem, as it were, to be determined by the movements of the volcano.

The height too of Etna is so great, that the lava frequently finds less resistance in piercing the flanks of the mountain than in rising to its summit, and has in this manner formed a number of parasitical cones, many of which possess their respective craters, and have given rise to considerable streams of melted matter.

Hence an ancient poet has very happily termed this volcano the Parent of Sicilian Mountains†, an expression strictly applicable to the relation it bears to the hills in its immediate neighbourhood, all of which have been formed by successive ejections of matter from its interior.

The grandest and most original feature indeed in the physiognomy of Etna, is the zone of subordinate volcanic hills with which it is encompassed, and which look like a court of subaltern princes waiting upon their sovereign.

Of these nearly eighty are enumerated; fifty-two on the west and north, twenty-seven on the east side of Etna; some covered with vegetation, others bare and arid, their relative antiquity being probably denoted by the progress vegetation has made upon their surface, in which respect the extraordinary difference that exists would be sufficient by itself to indicate, that the mountain to which they owe their origin must have been in a state of activity at a distance of time exceedingly remote.

It must be remarked, however, that the period requisite for bringing a bed of loose scoriæ or a stream of lava into cultivation varies very much‡, and that the progress made is gene-

* Such, according to Ferrara (Desc. dell Etna, p. 200), is the case with that of 1669, which Borelli calculated as containing 93,838,950 cubic feet.

† Σικελων ορεων πατερ' (Euripides in Troadibus).

‡ This will appear from the following statement of the condition of a few of the lavas of Vesuvius, which I examined with reference to this question in 1823.

Lava of 1551.—Fossa de Gaetano. Much decomposed. Heaths grow upon it, and vines begin to be planted.

rally more rapid in a cone of finely comminuted lapilli, than in a stream of lava, which consists of a hard glassy substance, that yields but slowly to the agents of decomposition.

There is nothing in the nature of lava, chemically speaking, injurious to vegetation; indeed when once decomposed, it supplies, as will be shown hereafter, all the elements of fertility—mechanically however the hard surface it presents proves an effectual preventative, as it gives no support or *nidus* to the tender shoots, and from its porosity often carries off all the moisture that descends upon its surface. Thus near Clermont, in Auvergne, scarcely a drop of water is to be found in the whole of the volcanic district which overhangs the town, but the streams collected from the hills above gush out at the bottom of this formation, in the valley of Royat beneath, with such force and copiousness, as to turn immediately several mills.

The surface then of a recent stream of lava must always be barren, unless, as has been done by the Prince of Biscari

Lava of 1737.—But little decomposed. Moss alone grows on it.
——— 1760.—Near the hill of the Camalduli. Still unfit for vegetation. Surface however whitened and crumbly, owing to decomposition, which has proceeded farther than in that of 1737.
——— 1771.—Colour grey; moss grows upon it, but no heath.
——— 1785.—Fossa di Sventurato. Lava still quite hard and rough.
——— 1794.—Fossa di Cucazzello. Surface much decomposed; moss grows upon it, and a few heaths, but no trees or shrubs. It is to be observed, that even the latter are met with on the surface of the crater from which this lava flowed, and which was formed by heaps of scoriæ ejected at the same time;—a proof of what I have asserted in the text with respect to the more rapid decomposition of loose ashes than of a bed of lava.
——— 1805.—Fossa del Noce. Colour very white; no moss appears to grow upon it, but, being covered with the loose scoriæ of later eruptions, it has trees growing upon it in a few parts.
——— 1810.—Colour grey; surface rough, though somewhat decomposed; moss grows upon it, but no heaths or trees are seen, except in one part where it is covered with cinders.
——— 1822.—Colour black; surface very rough and irregular; no moss as yet to be seen.

It will be seen that many of these lavas are in a more forward state than that of Ischia, which flowed in 1302, more than 200 years before.

in his garden at Catania, it is covered with artificial soil, or what comes to the same thing, a shower of volcanic ashes has overspread it of sufficient tenacity to imbibe moisture, and to form a sort of mould.

Under these circumstances I naturally felt a desire to verify an observation reported by Brydone on the authority of the Canon Recupero, which might render us suspicious of the correctness of our received chronologies. This writer, after giving an instance of a lava, the date of which, he says, goes back to the time of the second Punic war*, proceeds to state that at Aci Reale† we see seven such beds superimposed one on the other, each of which has its surface thoroughly decomposed, and converted into rich vegetable mould.

Now if a single bed of lava, he says, has continued for more than 2000 years without experiencing this alteration, what a lapse of time must it have required to reduce seven successive beds of the same material into a state of such complete decomposition!

Although I have no reason to doubt, that Brydone received from Recupero the observation on which he grounds his inferences, it seems

* The real date of this current was more ancient. It was that of the reign of the elder Dionysius tyrant of Syracuse.—*Vide infra.*

† The following is the passage to which I refer:—Near to a vault, which is now thirty feet below ground, and has probably been a burial-place, there is a draw-well, where there are several strata of lavas, with earth to a considerable thickness over the surface of each stratum. Recupero has made use of this as an argument to prove the great antiquity of the eruptions of the volcano. For if it requires two thousand years, or upwards, to form but a scanty soil on the surface of a lava, there must have been more than that space of time betwixt each of the eruptions which have formed these strata.

But what shall we say of a pit they sunk near to Jaci, of a great depth? They pierced through seven distinct lavas, one under the other, the surfaces of which were parallel, and most of them covered with a thick bed of rich earth. "Now," says he, "the eruption which formed the lowest of these lavas, if we may be allowed to reason from analogy, must have flowed from the mountain at least 14,000 years ago. Recupero tells me he is exceedingly embarrassed, by these discoveries, in writing the history of the mountain; that Moses hangs like a dead weight upon him, and blunts all his zeal for inquiry, for he really has not the conscience to make his mountain so young as that prophet makes the world. The bishop, who is strenuously orthodox—for it's an excellent see—has already warned him to be upon his guard, and not pretend to be a better historian than Moses, nor to presume to urge anything that may, in the smallest degree, be deemed contradictory to his sacred authority." (Brydone's Tour in Sicily, vol. i. p. 140.)

most probable that the remarks appended were in reality his own, though he thought to give them more zest, by putting them into the mouth of the Canon, whose scientific knowledge it was his aim to exalt at the expense of his orthodoxy. In reality however this good priest appears to have enjoyed in both respects a reputation which he very little deserved; the reports of Dolomieu* and other really scientific travellers making him out to have been a man of but slender philosophical attainments, but as one who at least was free from all imputation of scepticism. It is curious nevertheless, that another foreigner has stated, as an instance of the intolerant spirit prevailing in the country in which he lived, that the poor Abbé was thrown into prison for his religious opinions, whereas the truth appears to have been, that the reports circulated in his favour by Brydone, Borch and others, induced the Neapolitan government to grant him a pension on the score of his scientific merits. Indeed the only annoyance, it is said, he ever experienced in consequence of his imagined discovery, was the being informed that certain foreigners to whom he communicated his observation, not content with wresting it to a purpose of which he had never dreamt, had given him credit for inferences which they had chosen to deduce from it themselves.

The fact nevertheless reported by Brydone obtained a currency proportionate to the popularity which his work enjoyed; and the mode in which the conclusion drawn from it had been generally combated, was by reference to the great variableness as to the period which a bed of lava will take to undergo decomposition. Thus even Spallanzani, though he visited Sicily, seems to have contented himself with pointing out instances in which newer beds of lava have taken the start of older ones in their progress towards cultivation†, a circumstance now explained by the fact, that lava, like basalt, is not in general a homogeneous body, but in reality is made up of an intimate mixture of at least two minerals in different proportions, which are unequally affected by decomposing agencies.

Supposing therefore the fact stated by Brydone to be unquestionable, I was not a little surprised, when on visiting the celebrated spot adverted to, I found the beds of vegetable mould, which proved, according to that author, the degree to which the decomposition of the lava had extended, to be in reality nothing more nor less than layers of a ferruginous tuff, formed probably at the very period of the flowing of the lava, and originating perhaps from a shower of ashes that immediately succeeded its eruption. It is true that the cliff, which

* See Dolomieu sur les Iles Ponces, p. 470.

† Voyage dans les deux Siciles, vol. i. l. 7.

exhibits a section of these lava beds with interposed tuff, shows also the greater facility with which the latter has yielded to the action of the elements, as the bare and mural precipices presented by the lavas are in marked contrast with the gentle slope of the beds of tuff, which afford soil sufficient for the hardy Cactus, and in some places even for the Vine. Still there is not the slightest evidence that the decomposition extends internally, or that it had taken place in any one instance before the superincumbent bed of lava was deposited.

It seems also very doubtful whether these beds have resulted from the operations of Mount Etna, at least in modern times; for if we examine their characters, we shall find them sufficiently distinguished by greater compactness and a stony aspect from modern lavas, whilst the general correspondence in mineralogical characters that exists between them all affords a strong presumption of their having been produced about the same period.

But it is useless to multiply proofs of the fallacy of Mr. Brydone's statement, and the only circumstance that needs surprise us is, that so many years should have elapsed, without any traveller having visited the spot with the view of ascertaining the correctness of his observations.

What the real antiquity of this volcano may be, will depend in our estimation upon the theory we prefer to adopt with respect to the mode of its formation.

If with some geologists we imagine it wholly built up by successive eruptions of lava and ejected masses mantling round some central nucleus, like the concentric rings of a dicotyledonous tree, to use a simile of Mr. Lyell's, the period occupied in the production of so enormous a mass would indeed be inconceivably great, for the ejections of sixteen centuries have added only a few feet to that part of the mountain upon which was erected the Torre del Philosopho, the remains, as it is said, of the watch-tower or observatory of Adrian.

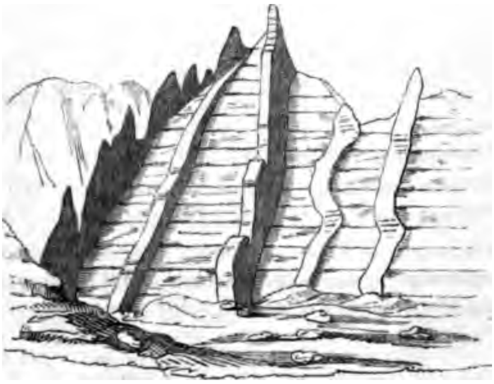
But the difficulties of another kind, which stand in the way of this supposition, have led several distinguished geologists to apply to the case of Mount Etna the elevation theory of Von Buch, and to take a view of the early history of the mountain, differing materially from one built upon that series of events which has been taking place in it during the period of man's observation.

It is only of course a persuasion, that the phænomena ex-

hibited by the inner portions of the volcano revealed to us are irreconcilable with the results of its present operations, which can induce us to do violence to our natural prepossessions in favour of that uniform march of events which the common theory assumes. But it must be confessed, I think, even by the warmest partisans of the latter, that we have only the alternative of supposing nature to have operated at some former period in a different manner, that is, under different circumstances from those existing at the present, or to have brought about in ancient times products different from those of the present day by the same kind of operations.

Now there is a remarkable valley on the east side of Etna, commencing near the summit, and descending with its prolongations to the confines of the fertile or lower region of the mountain, which affords a natural section of the internal portions of the volcano. It is called the Val di Bove, and has been graphically described by Mr. Lyell in his 'Principles of Geology.' He represents it, as a vast amphitheatre four or five miles in diameter, surrounded by nearly vertical precipices varying from 1000 to above 3000 feet in height, the loftiest being at the upper end, and the height diminishing on both sides, remarkable for the infinite number of vertical dykes which are seen traversing the volcanic beds composing it.

The following representation of some of them is taken from Mr. Lyell's work. The dykes represented vary in breadth from two to twenty feet, and usually project from the face of the cliff as here seen.



Dyke at the base of the Serre del Solfizio, Etna.

On one point of theory most geologists seem agreed, namely, that the vast mass of matter which at one time must have filled up this immense cavity, has probably sunk into the interior of the volcano.

They are also agreed as to the fact, that the beds which are seen surrounding the valley have not that quâquâ-versal dip which is generally regarded as characteristic of a crater, but are all inclined towards the sea, or nearly east at a considerable angle.

So far therefore the appearances would seem to be unfavourable to the elevation theory; for if the mountain owed its origin to an upheaving of the surface, the Val di Bove would be the point where we might expect to find the evidence of such a catastrophe.

It has also been ascertained* that the lavas of the Val di Bove, though differing in external appearance, compactness, &c., as well as in the presence of hornblende, from those at present ejected from the mountain, agree with them nevertheless in consisting of Labrador felspar destitute of potass, and not of either of the trisilicates belonging to that *genus* †. Hence the notion that the nucleus of Mount Etna is tra-

* See Hoffman, Geog. Beob. p. 692.

† This however does not appear to be the case universally, for in a note to page 702 of Hoffman's work edited by Von Dechen, it is stated that the rock of Giannicola in the Val di Bove had been analysed by Plattner, and that after separating as much as possible by mechanical means the particles of hornblende, the remaining felspathic portion was found to consist of—

		Or deducting the iron and manganese as extraneous,
Silica	62·2	65·00
Alumina	20·8	22·00
Lime	2·7	2·80
Magnesia	1·4	1·50
Oxide of iron & manganese	4·3	
Potass	3·1	3·25
Soda	5·2	5·45
	99·7	100·00

Now by referring to page 13 of this work, it will be seen that this approaches very nearly to the composition of the potass-albite of Drachenfels in respect to the proportions of potass and soda, but that those of the other ingredients differ widely. It is therefore probable that two kinds of felspar may here be intermixed.

chytic, which Gioeni and others have represented it to be, and which analogy might lead us to conjecture was the case, is at least not confirmed by the examination of the Val di Bove.

Notwithstanding all this, Elie de Beaumont* has brought together a great array of evidence in support of his position, that the beds of the Val di Bove could not have been deposited at their present high angle of inclination, which amounts in some cases to thirty degrees. He appeals to the uniformity of their thickness, their compact and crystalline character, and to the absence of that *talus* of scoriæ which accompanies most currents, characters belonging, as he contends, exclusively to those lavas which have flowed at a very small angle, and which consequently only begin to be assumed by the products of modern eruptions when they have reached the level ground.

From these and other reasons which are urged by this eminent geologist with great ingenuity and force, it is concluded, that the ground now covered by Mount Etna was originally nearly flat, but that it was rent at various times by fissures running nearly in one determinate direction; that through these fissures issued the melted matters, which spreading on all sides of the orifice formed vast sheets; and that these, owing to the equal distribution of the matter from a number of different vents, became nearly uniform in thickness. These eruptions were followed by ejections of loose masses, which formed the beds of tuff superposed.

But at one period the agent, which had so often rent the ground, acquired a force sufficiently great to upheave it. From that moment Etna became a mountain, and a channel of communication between the interior of the globe and the atmosphere being established up to its very summit, a permanent volcano was the consequence.

The elevation however does not appear to have taken place in the same simple manner as in those localities where it has given rise to regular craters of elevation, such as that of Monte Somma. The effort which has upheaved the gibbous portion of Etna seems to have acted, not at one central point, but along a straight line represented by the axis of an ellipse, of which the southern, northern and eastern flanks of the Val

* Mémoires pour servir, &c. vol. ii.

di Bove constitute the different portions; and the elevatory force appears to have acted unequally on the different portions of this line, so that its western extremity, which corresponds with the actual chimney of the volcano, has been upheaved more than the rest.

The upheavement then of this portion of the mountain was accompanied, in all probability, with the engulfment of the great mass of matter which must have once filled the actual cavity, and thus the void which the upheaving of the mass would occasion within may have been partially supplied. Nor need such an event as is here supposed, be regarded as implying any violation of, or departure from, the ordinary laws of nature.

"It is impossible to say," remarks M. de Beaumont, "how many generations must succeed each other on the borders of a river, in order that the people that dwell there should have registered in their annals all the droughts, all the excavations, all the irruptions and anomalies of every sort which the stream is liable to produce. Still more ignorant are we what lapse of time may be required, in order that any one volcanic focus should run through the entire circle of accidents of which it is susceptible, not to speak of that, which those in other parts of the world are capable of exhibiting."

Elie de Beaumont therefore would divide the products of this volcano into two classes, ancient and modern, placing the volcanic rocks exhibited in the Val di Bove, as well as many of those found at the base of the mountain, under the former category, and the rocks surrounding the present crater, together with its numerous subordinate cones and their respective streams of lava seen on the surface of the mountain, under the latter.

This crater, when visited by Hoffman in 1832, was a funnel-shaped elliptical cavity, surrounded by precipitous walls. The larger diameter might be 1000 paces, the smaller 600. The walls rose from 300 to 350 feet above the general level; on the west side they are seen to consist of horizontal beds of slag, but elsewhere they present nothing but perpendicular fissures, from which abundance of vapours issue. These appear to have been sulphureous, as was the case when I visited the crater in 1824, whereas those emitted from Vesuvius consisted of muriatic acid. Hoffman observed, that in 1829 a

small lava-stream was emitted from the crater, which, considering its great height, is a remarkable circumstance. In this volcano however the resistance opposed in the lower parts of the mountain is so great, that the lava streams seldom issue from it at a lower point than Nicolosi, which is 2286 feet above the sea.

With regard to the history of the volcano as deduced from records or traditions, I may remark, that the silence of Homer on the subject of the eruptions of Etna is often quoted in proof, either of its more modern date, or of its having been, like Vesuvius, in a state of long quiescence*; but to such *negative* evidence we have to oppose the *positive* statement of Diodorus Siculus†, who notices an eruption long anterior to the age of this poet, as he says that the Sicani, who with the exception of the fabulous Cyclops‡ and Lestrigons, were the first inhabitants of the island, and who are admitted on all sides to have possessed it considerably before the Trojan war, deserted the neighbourhood of Mount Etna in consequence of the terror caused by the eruptions of the volcano.

This is confirmed by Dionysius Halicarnassus, who reports that the Siculi §, who passed over from Magna Græcia about eighty years before the Trojan war, first took possession of that part of the island which had been deserted by the Sicanians, so that it is probable that the mountain was at that period tolerably tranquil, in which case, supposing no eruption to have taken place from that time till the age of Homer, it is by no means unlikely that in a barbarous age the tradi-

* It is true that the fire of Etna is alluded to in the poems attributed to Orpheus, which some have supposed as ancient as the time of Pisistratus, half a century at least before the age of Pindar: these poems however are in general referred to a much later period.

† Lib. v.

‡ Fazzello, Decad. lib. i. l. 6, tells some wonderful stories of the bones and teeth of these giants being discovered in caverns in the limestone of Trepani, Palermo, &c.; but these have been examined by Dr. Christie, Professor Scina, and others, and are found to consist of the bones of elephants, hippopotami, deer, &c. Edinb. Ph. Journ., April 1832.

§ Dion. Hal. lib. i. There is great uncertainty however respecting the date of this event. Cluverius places it 148 years after the taking of Troy (Sicilia Antiqua, p. 29), but Thucydides expressly says, lib. vi., that the Siculi came over 300 years before the Greeks, who were driven to Sicily by a tempest on their return from Troy.

tion of events so remote may have been in great measure effaced, and thus have never reached the ears of the Greek poet.

The earliest historian by whom the volcano has been noticed is Thucydides, who says, that up to the date of the Peloponnesian war, which commenced in the year 431 B.C., three eruptions had taken place from Mount Etna since Sicily was peopled by the Greeks. It is probably to one of these that Pindar has alluded in his first Pythian Ode*, written according to Heyne in consequence of the victory obtained by Hiero in the year 470 B.C. It may be remarked, that this poet particularly speaks of the streams of lava, which, if we may judge from Vesuvius, are less usual concomitants of the first eruptions of a volcano †.

Τας ερευγονται μεν ἁπλα—
Του πυρος ἁγνοταται
Εκ μυχων παγαι, ποταμοι
Δ'αμεραισιν μεν προχεοντι ῥοον καπνου
Αιθων'.

Diodorus Siculus ‡ mentions an eruption subsequent to the above, namely in the 96th Olymp. or 396 years B.C., which stopped the Carthaginian army in their march against Syracuse. The stream may be seen on the eastern slope of

* Æschylus as well as Pindar alludes to the confinement of Typhon under the island of Sicily, and to the volcanic eruptions arising from his presence :—

Και νυν, αχρειον και παρηορον δεμας
Κειται στενωπου πλησιον θαλασσιου
Ιπνουμενος ῥιζησιν Αιτναιαις ὑπο.
Κορυφαις δ'εν ακραις ἡμενος μυδροκτυπει
'Ηφαιστος, ενθεν εκραγησονται ποτε
Ποταμοι πυρος, δαπτοντες αγριαις γναθοις
Της καλλικαρπου Σικελιας λευρας γυας.

Prometheus, 363.

It may be remarked that this poet speaks of the volcanic phænomena as to happen at some time subsequent to that at which the incidents of the play are supposed to take place, and as being, at the period to which he refers, only in preparation.

† In case any doubt should exist respecting the interpretation of this passage, it may be remarked, that the existence of a stream of lava is more distinctly expressed by Thucydides, whose words are: *ἐῤῥυη περι αυτο το εαρ τουτο ὁ ῥυαξ του πυρος εκ της Αιτνας.*—L. iii. 116.

‡ Lib. xiv.

the mountain near Giarre, extending over a breadth of more than two miles, and having a length of twenty-four from the summit of the mountain to its final termination in the sea. The spot in question is called the Bosco di Aci; it contains many large trees, and has a partial coating of vegetable mould, and it is seen that this torrent covered lavas of an older date which existed on the spot.

Four eruptions are recorded to have happened between this period and the century immediately preceding the Christian æra*, during which latter epoch the mountain seems to have been in a state of frequent agitation, so that it is noticed by the poets among the signs of the anger of the gods at the death of Cæsar †.

After this for about a thousand years its eruptions are but little noticed, but during the last eight centuries they have succeeded each other with considerable rapidity. Referring however to the chronological list of the eruptions of the mountain for a specification of these, I shall here merely allude to such as have produced some remarkable change in the character of the country.

I know not whether I ought to include among these events the supposed destruction of the port of Ulysses and the island adjoining, of which Homer and Virgil make mention, and which, from the position assigned to them by Pliny ‡, have been supposed to have stood near the village of Longnina, a few miles north of Catania.

As the present size of the creek which is found there, adapted only for small fishing-boats, is far too inconsiderable to correspond with the description given of it by the poets §, and as the island itself does not exist, it has been imagined that there was once a harbour farther inland, and at the back of the present village, an idea to which the configuration of

* viz. B.C. 140, 135, 126, 122. Cluv. Sic. Ant. p. 105.

† ——— Quoties Cyclopum effervere in agros
Vidimus undantem ruptis fornacibus Etnam,
Flammarumque globos, liquefactaque volvere saxa.
Georgic. i. 471.

‡ Plin. Nat. Hist. lib. iii. cap. 14.

§ Portus ab accessu ventorum immotus, et ingens
Ipse, sed horrificis juxta tonat Etna ruinis.—*Æneid.* iii. 571.

the surrounding country seems to lend some colour. Bembo* even goes so far as to attribute to an eruption that took place in the fourteenth century, the filling up of the harbour, and the junction of the island with the main land, and Fazzello follows him in this notion; but Ferrara † assures us, that the lava of Longnina certainly belongs to the eruption recorded by Orosius as happening in the year of Rome 631, or 122 B.C., so that the destruction of the port must have occurred at that epoch, if at all. It must be remarked however that, with the single exception of Pliny, no notice is taken of such a port by any of the prose writers of antiquity, so that it is possible that the whole may have been a figment of imagination, first introduced by Homer, and copied with little variation by his Roman imitator.

The only semblance of a harbour which the neighbourhood of Catania has to show, it owes to the lava of 1669. In this memorable eruption a rent twelve miles in length and six feet in width took place on the flank of the mountain above Nicolosi, about half-way between Catania and the summit, and from this fissure descended a torrent of melted matter, which continued flowing for several miles, destroyed a part of Catania, and at length entering the sea formed a little promontory, which serves at present to arrest the fury of the waves in that quarter. At the same time the accumulation of matters ejected raised on the mountain two conical hills called the Monti Rossi, which measure at their base about two Italian miles, and are in height more than 300 feet above the slope of the mountain on which they are placed.

The eruption of 1755 was remarkable from an overflow of water, an enormous torrent of which burst from a cavern below the great crater, dashed over the snows, and pouring down the precipices, overwhelmed and destroyed everything that interposed, in its irresistible descent. The water is said to have been boiling; but this Mr. Lyell disputes, although, if it proceeded from the *interior* of the mountain, and not from the melting of snows on its exterior, its temperature would necessarily have been high. Unfortunately it is not

* See P. Bembi Liber de Etnâ, attached to Schelte's edition of Corn. Sever. Etna. Amstel. 1703, p. 218.

† Ferrara, Descrizione dell' Etna. Palermo, 1818.

settled whether the water was salt or fresh: had this been ascertained, its origin would not have continued doubtful.

The eruption of 1819 is particularly described by Signor Gemellaro of Catania, who has for many years past carefully watched and recorded the operations of the volcano.

Three large openings occurred in the side of the cone not far from its apex, from which flames, red-hot lapilli, and sand were thrown up. Two other apertures immediately afterwards took place a little underneath, from the lowest of which a torrent of lava proceeded. This was augmented by streams from the other four craters, which, uniting into one body of molten matter, poured themselves into the Val di Bove. There, according to Mr. Scrope, its surface presented that rugged and irregular aspect which belongs to lava-streams flowing down a considerable slope, and advancing consequently at a comparatively rapid rate.

It had all the appearance, he says, of a huge heap of rough and large cinders rolling over and over upon itself, by the effect of an extremely slow propulsion from behind. When it arrived at a vast and almost perpendicular precipice at the head of the valley of Catania, it poured over in a cascade, and being hardened in its descent, made an inconceivable crash as it was dashed against the bottom, throwing up an enormous mass of dust from the abrasion of the tufaceous hill over which it had descended.

In the year 1831 the operations of the volcano assumed an additional interest from their presumed connexion with certain movements which were observed in the sea off the coast of Sciacca, and which terminated in the elevation of a new island.

That the volcanic energy exerts itself generally under the neighbouring parts of the Mediterranean might indeed have been inferred from a phænomenon noticed by Captain Smyth, and called by the Sicilians Marobia, probably a corruption of Mare Ubbriaco, or the drunken sea, a name which it derives from the irregular movement of the waters which takes place principally along the southern coast of the island and in calm weather, although regarded as the precursor of a storm. The Marobia is felt with the greatest violence at Mazzara; its approach is announced by a stillness in the atmosphere and

a lurid sky, when suddenly the water rises nearly two feet above its usual level, and rushes into the creeks with amazing rapidity; but in a few minutes recedes again with equal velocity, disturbing the mud, tearing up the seaweed, and occasioning a noisome effluvia, during which time the fish float quite helpless on the turbid surface, and are easily taken. These rapid changes (as capricious in their nature as those of the Euripus) generally continue from thirty minutes to upwards of two hours, and are succeeded by the breeze from the southward, which quickly increases to heavy gusts.

Whether or not this be owing to a volcanic cause, we may at least assign to the latter a phænomenon called the *mare-moto*, which is experienced off the coast of Sicily, and is the same in its effects at sea as an earthquake on shore; nor will it appear unnatural that the sea should be thus agitated, when I relate the event alluded to as occurring off the western coast of Sicily in the year 1831, at the very time when Etna was throwing out smoke and volcanic sand, as this was preceded, within a fortnight of its occurrence, by the *sea-quake* here, of which mention has been made*.

The volcano was first observed by a merchant vessel on the 13th of July 1831. It was afterwards approached by Captain Swinburne, the commander of an English sloop of war, and was reported by him to be on the 19th of July in a state of great activity, emitting vast volumes of steam, ashes, and cinders, and having a crater raised only a few feet above the sea's level. The eruptions lasted till nearly the end of August, when the circumference of the island was about 3840 feet, its greatest height 107, and its crater 780 feet. On the 5th of August it was visited by Dr. Davy, who found it in the act of emitting, at intervals of two or three hours apart, volumes of white vapour, mixed with occasional showers of ashes. No sulphureous smell was perceptible, but abundance of gas was given off from the sea in its immediate neighbourhood, which proved to consist chiefly of carbonic acid and of azote, but with scarcely a trace of sulphuretted hydrogen.

The portion of the island which projected above the waters appeared to consist wholly of loose scoriæ, or fragments of vesicular lava; it continued visible till the latter end of December, when it sunk again beneath the waters, leaving not a rock or even a shoal to mark its position.

Whether, however, it is to be regarded as a portion of the

* See Commander Swinburne's Despatch to Admiral Hotham.

bed of the Mediterranean upheaved by the volcanic forces which found a vent through the crater on the summit, or whether it was simply built up by a congeries of loose fragments and scoriæ ejected from the bottom of the sea, is still a matter of dispute. The latter is the most obvious hypothesis, and is the one adopted by Dr. Davy and by M. Constant Prevost, both of whom were on the spot. It is subject however to very serious difficulties, from the great depth of the sea at the spot where this new island arose, and the rapid sinking of the soundings from one to forty or fifty fathoms. Had the island been built up by a gradual accumulation of loose fragments, would not some time have been required for raising it to such an elevation; and ought not the bottom of the sea for many miles around to have also had its depth diminished? Moreover, it is a curious fact recorded by Davy, that whilst the temperature of the sea at the time was in general 80°, that immediately above the island reached only 70° or 72°, a circumstance which M. Arago explains in accordance with the elevation theory, by supposing a mass of rock possessing a lower temperature to have been thrust up through the midst of the waters.

The last eruption of any moment which has taken place at Mount Etna was the one of December 1842, which produced a stream of lava taking the direction of Bronte and Randazzo, and producing great devastations. A curious circumstance is recorded of it, which has given rise to much discussion. The lava-stream was watched by a large number of persons proceeding steadily onwards, in the direction of a small lake or pond of water. When it approached its borders, the first impulse of the assembled multitude was to retreat, aware of the consequences which usually attend the contact of molten matter with a body of liquid. To their surprise however no explosion took place at the moment the lava reached the pool, upon which a number of the spectators took courage, and went nearer to watch what would happen. After a brief interval, however, the effects which they had shrunk from with so much dread actually occurred, the lava which had entered the stream being suddenly projected into the air with a terrific noise, and the fragments in their descent proving fatal to a large number of those who had been rash enough to come near.

M. Boutigny, whose ingenious experiments on the repulsion between bodies intensely heated and water are well known, explains the non-occurrence of any explosion at the moment of the lava first entering the water, by its high temperature, which was such, as not to cause the generation of steam till it had had time to cool down to a certain point, when the usual consequences of the contact of a heated mass with water took place.

With regard to the products of volcanic action exhibited at Mount Etna, I may state generally, that its lavas have been determined by Professor Rose to consist of an intimate mixture of labradorite and of augite, seldom containing any hornblende, and never orthoclase. Hence the entire absence of pumice and of obsidian; for these, as has been already stated, are products of felspathic rocks, in which the several earths and alkalies exist in the compound as trisilicates.

There is therefore a general correspondence in character between the ancient and modern lavas, except that the latter contain more generally an admixture of titaniferous iron. The ejected masses are much more uniform in their composition than those found on Vesuvius, nor am I aware of the occurrence among them of any mineral that does not exist in the latter mountain. Signor Gemellaro discovered a mass of granite in the midst of ancient lava * which seemed to have been thrown out from the volcano.

To the same geologist we are also indebted for a very singular discovery, namely that of a bed of ice, interstratified, as it were, with lava near the Casa Inglese, at a height of about 9000 feet, owing, as it would appear, to a stream of melted matter having flowed over a deep mass of drift snow, protected from its immediate contact by the dense stratum of volcanic sand or ashes which covered it, this being so bad a conductor of heat as to prevent the entire fusion of the frozen mass underneath. When once consolidated, the lava would itself protect the ice from further disturbance, and hence it is quite conceivable, that repeated alternations of snow and lava might occur, especially in the volcanos of colder regions.

* See his pamphlet "Sopra alcuni pezzi di Granito e di lava anticha trovati presso alla cima di Etna," del Dottor C. Gemellaro. Catania, 1823.

During the period at which I visited the mountain, in 1824, sulphurous acid was given out in volumes from the crater; but the condensed vapours collected from the fumaroles on its exterior consisted simply of water, very slightly impregnated with muriatic acid. Sulphuretted hydrogen I did not discover near the summit, but at the bottom of the mountain it is evolved from the spring of Santa Vennera near Jaci Reale.

Table, showing the correspondence in point of time between the eruptions of Etna, Vesuvius, and the other Volcanos connected with them.

(Extracted, with some few additions, from Hoff's Geschichte der Veranderungen der Erdoberflache*.)

ETNA.		VESUVIUS.
B.C.		
480 or thereabouts.		
427.		
396.		
	185, Eruption between the Æolian Islands, according to Pliny, 200 B.C.	
140.		
135.		
126 or 125, in which year flames rose from the sea near Lipari.		
122.		
	91, Eruption at Ischia.	
56 or thereabouts.		
45 or 44.		
36 or thereabouts.		
A.D.		
40 or thereabouts.		A.D.
		79.
		203.
251.		
		512.
		685.
812.		
		983.
		993.
		1036.
		1049.
		1138 or 1139, 6 Kal. Iun.
1169, Feb. 4.		
Between 1198 and 1250.		
	1198, the Solfatara inflamed.	
1284.		
	1302, Eruption of Mount Epomeo, in Ischia.	

* Those who wish to learn more respecting the earlier eruptions of Mount Etna may consult a memoir by the Canon Alessi, in the Transactions of the Gioenian Society of Catania, 1826.

ETNA.	VESUVIUS.
A.D.	A.D.
	1306.
1329, June 28.	
1333.	
1408, November 9.	
1445.	
1446.	
1447, September.	
	1500.
1535, March, till 1537.	
1538, 29th September, Formation of the Monte Nuovo, near Puzzuoli.	
1566. 1578. 1603, July. 1607. 1610, Feb. 1614, July 2. 1619. 1624. Continuance of small eruptions during this interval.	
	1631, December 16.
1633, February 22.	
1645, November.	
1654.	
	1660, July.
1669, March 8.	
1682, December.	1682, August 12.
1688.	
1689, March 14.	
1694, March to December. (Eruption only of ashes.)	1694, March 12, with feeble recurrences of action till 1698.
	1701, July 2 till 15.
1702, March 8.	
	1707, May 20, with feeble recurrences of action till August 1707.
	1712, Feb. 18, eruption continued till the following year.
	1717, June 6, continued as before.
1723, November, beginning of the month.	
	1727, July 26.
	1730, February 27.
1735, October, beginning of the month.	
	1737, May 14.
1747, September, volcanic action continued for some years.	
	1751, October 25.
	1754, December 2.
1755, March 2.	
1759.	
	1760, December 23.
1763, June 19.	
1766, April 27.	1766, March 25.
	1767, October 23.
	1770.
	1778, September 22.
	1779, August 3.
1780, May 18.	
1781, April 24.	
	1783, August 18.

ETNA. A.D.	VESUVIUS. A.D.
	1784, October 12 and December.
	1786, October 31.
1787, July 28.	1787, December 21.
	1788, July 19.
	1789, September 6.
1792, March.	
	1794, June 15.
1798, June.	
1799, June.	1799, February.
1800, February 27.	
1802.	
	1804, August 12 and November 22.
	1805, July.
	1806, May.
1809, March 27.	1809, December 10.
	1811, October 12.
1811, October 28.	1811, December 31.
	1813, May to December.
	1817, December 22 to 26.
	1818.
1819, May 29.	1819, April 17.
	1819, November 25.
	1822, February 13 to 24.
	1822, October 22.
	1830, August 18.
1831, February 17, appearance of a new island off the coast of Sciacca, first observed July 13.	
1832, Oct. 31.	
	1834, August.
	1839, minor eruptions of scoriæ, &c.
1842, December.	
	1845, ditto.

It appears from this Table, that the nearest coincidence between the eruptions of the two volcanos was in 1694 and in 1811, when they occurred within a month of each other; and that on eight several occasions an interval of less than half a year elapsed between them: viz. that of Vesuvius Dec. 2, 1754, was followed by one of Etna on March 2, 1755; Vesuvius August 3, 1779, by Etna May 18, 1780; Vesuvius October 31, by Etna July 28, 1787; Etna June 1798, by Vesuvius February 1799; again followed by one of Etna in June, same year; Etna March 27, 1809, by Vesuvius December 10, 1809; Vesuvius October 12, 1811, by Etna October 25, 1811; again followed by Vesuvius December 31, same year; Vesuvius May 27, 1819, by Etna November 25, same year.

The above-mentioned coincidences do not appear to me sufficiently numerous to warrant the inference, that a connexion subsists between these two igneous vents; nor does such an idea tally with the views of Von Buch, who regards both Etna and Vesuvius as *central volcanos*, that is, as points of greatest intensity, from which the igneous energy radiates in all directions, as from a centre.

It seems to me more probable, that whilst volcanic forces

have been, or are in operation on either side of the Apennine chain, from the north of Italy to its very southern extremity, and to the island of Sicily beyond, there are certain transverse lines along which these forces manifest themselves in their greatest intensity, either by their actual phænomena, or by their past effects. Such is the line from Ischia to Vesuvius, the lake Amsanctus and Mount Vultur; that perhaps extending from Latium to the Tremite Islands, which are stated to be volcanic; and lastly, the one running from Mount Etna to the hot springs of Sciacca, thence intersecting the new island thrown up in 1831, and terminating in Pantellaria.

Pantellaria.

Of this last island Hoffman has presented us with a short account. It is situated at a distance of sixty miles to the south-west of Sciacca, the new island thrown up in 1831 being about midway between it and the coast of Sicily.

He distinguishes three kinds of volcanic products: the first a peculiar kind of felspar with a greenish colour and slaty cleavage, which he calls *chloric* lava; crystals of glassy felspar, and of a black needle-shaped mineral which resembles hornblende, are disseminated through this basis.

The second kind of igneous rock is of a glassy character like that found in Lipari, consisting either of pumice in such vast heaps as to form a hill 2000 feet high, or of obsidian, which in some places constitutes lava-streams. Steam issues from many parts of this mountain, and several hot springs gush out from it, which form together a little lake 6000 feet in circumference.

The third kind of volcanic product met with consists of lava-streams similar to those of Mount Etna, and therefore altogether different from the pumiceous products before mentioned. They consequently appear to belong to a more recent period, although no record exists as to any eruptions occurring in the island.

There appear to be the remnants of an ancient crater of elevation encircling a space of 12 miles, and composed of beds of the trachytic lava and of the pumiceous conglomerate above described.

CHAPTER XVI.

SARDINIA—SPAIN—PORTUGAL.

Sardinia—modern volcanic rocks—consisting of trachyte—obsidian, &c. —Spain—its structure compared with that of Mexico—volcanic rocks—in Catalonia—near Carthagena—Cape de Gaieta.—The Colubretes.—Portugal—basaltic rocks near Lisbon.—Indications of volcanos in the Sierra l'Estrella—Cape St. Vincent, &c.

Before proceeding to a description of other active volcanos existing in the same quarter of the globe, it may be more convenient to point out those evidences of former igneous action not already described, which have been recognised in parts of Europe situated within the confines of the Mediterranean.

First then I may remark, that, according to the researches of M. de la Marmora, the island of Sardinia exhibits evident traces of volcanic eruptions, both of an ancient and a modern date, though not comprised within the limits either of history or tradition.

It may be collected from his statement, that the volcanos occur in almost every case in groups of greater or less extent, and that they in general repose on rocks belonging to the most recent order of formations. Parts of these products are of a date posterior to the excavation of the valleys, but others are distinctly recognised as anterior to them. Thus, in the south of the island, between the village of Nurri and the plain called Campidano, the calcareous rocks of the country are capped by a platform of well-characterized lava, which follows the general inclination of the country from east to west.

The name given to these platforms is Giarra, and there are several of them, such as the Giarra de Serri, de Gestori, &c.

The inclination of the beds, the direction of the cells, and the abundance of the lava which is found alike on the summits of all the calcareous and marly hills of this neighbourhood, lead to the belief that their origin is in all cases the same, or that they belong, to speak more correctly, to one and the same current that proceeded from a crater near Nurri,

at an epoch antecedent to the period at which the valleys were excavated.

The craters are in great measure effaced, and it is only with hesitation that our author admits that there exist traces of any. In his search he was directed rather by the shape and direction of the cells found in the lavas, than by the actual form of the masses themselves.

Among the volcanic formations of this island, the predominant rock is a felspathic (petro-siliceuse) porphyry. It constitutes two-thirds of the *lithoide* lavas of the country. It occurs in great masses on the two islands already cited; among the mountains of Ales, Bortigali, and the environs of Macomer; forms a large portion of the mountains called Villa Nuova, Monte Leone, and Bosa; and is found at last at Ploaghe, near Osilo and Castel Sardo, where it passes into obsidian.

The most remarkable variety which this porphyry presents is a rock of a prismatic form with a fine rosy hue, often ramified with dendrites. It has been observed in the islands of St. Pietro, St. Antioco, and Isola Prima, and affords the only instance of a prismatic structure present amongst the rocks of this quarter. Those portions which are preserved from the action of air and light retain a very bright colour, the lustre of which is relieved by fine ramifications of very large and varied dendrites.

The island of St. Antioco is also very rich in pearlstone, which constitutes part of a species of conglomerate or breccia, inclosing likewise other substances, this pearlstone seeming to have been rolled, and occurring in masses from the size of a nut to that of twice or thrice a man's head. It is always accompanied with puzzolana. Obsidian with a conchoidal fracture occurs in the island of St. Peter's, on the summit of Trebina, near Ales, &c., but true pumice has not been met with.

Red jasper abounds, especially in the Isle of St. Peter, and in the volcanic rocks of Alghero, Eteri, and Bosa, and basaltic lavas, often scoriform, form the greatest part of Monte St. Lussurgio and of Caglieri. On the eastern flank of the former mountain we observe the lava that flowed from its extinct crater.

Spanish Peninsula.

The physical structure of Old and of New Spain, no less than their political condition, so far as the latter has been influenced by that circumstance, presents, along with many differences, some striking and somewhat unexpected analogies.

Both countries appear to have been raised above the level of the sea at a period comparatively recent, and in such a manner as to constitute a table-land of considerable elevation and of wide extent, equidistant from two seas. Both consequently enjoy a climate considerably cooler than would be expected to belong to them considering their respective latitudes, and possess a vegetation more analogous to that of countries situated to their north, than of those in the same parallel of latitude.

Both too are remarkable for their mineral wealth; Old Spain having occupied in this respect during the period of the Roman dominion the same place which New Spain has done in modern times; and now that it is thrown upon its own resources by the loss of its colonies, beginning to resume in this respect its former position as a mining country.

But if we inquire more particularly into the mineral structure of the two regions, nothing can present more striking contrasts. Whilst the table-land of Mexico consists, as we shall afterwards find, of trachyte and other rocks of igneous origin, and is surrounded by volcanos still in activity, that of Old Castile is a nearly level plain, consisting either of tertiary rocks of very recent origin, or of pebbles derived from the detritus of older formations; whilst the only vestiges of the igneous action which may be supposed to have upheaved this continent are seen at a great distance off, near either coast, as near the Pyrenees in Catalonia, and more southwards in the neighbourhood of Murcia and Alicant on the eastern, and in a few parts of Portugal on the western side of the Peninsula. I propose to give a short account of these, beginning with the volcanic phænomena observed in Catalonia.

Volcanic Rocks of Catalonia.

Dr. Maclure, the American geologist, appears to have been the first person to describe this volcanic district; but a more

accurate and complete account of it has since been given by Mr. Lyell*.

The whole extent of country occupied by volcanic products in Catalonia, is not more than fifteen miles from north to south, and about six from east to west. The vents of eruption range entirely within a narrow band running north and south, and the branches extending eastward of this line are formed simply of two lava-streams, those of Castell-Follet and Cellent. About fourteen distinct cones with craters exist along this line, the most perfect being situated in the neighbourhood of the town of Olot. The level plain upon which the latter is built has been produced by the flowing down of many lava-streams from the hills above into a valley which they have filled up to a considerable height. The river Fluvia, which passes near the town, has cut through these lavas to the depth of forty feet, exposing two distinct lava-currents of a basaltic character, separated one from the other by a horizontal bed of scoriæ eight feet thick.

In other places however the lava has been excavated to a much greater depth. Thus in the bottom of a valley, in which a stream ran with great velocity owing to the slope of the ground, the amount of excavation is no less than 100 feet. The lava-streams rest upon the gravel of the country, and follow the slope of the existing valleys, nor is there anything in the appearance of the rocks themselves or of the craters, to distinguish the volcanos from whence they originated from those of the present day. The former consist of red scoriæ as fresh as if they had been erupted yesterday, the latter are often as perfect as those of Etna or Vesuvius. They belong therefore to the class of modern, although no records exist of any eruption from them. Earthquakes indeed occur, as in 1421, when the whole of the town of Olot was thrown down, but it does not appear that the shock was accompanied by any volcanic eruption.

The rocks from which the volcanos have been erupted belong to the new red sandstone with salt, of which the neighbouring mountain of Cardona affords so remarkable an example, and likewise to the nummulitic limestone, probably of the age of our chalk.

* Principles of Geology, vol. iii. p. 185.

It is remarkable, that whilst the volcanic district above described lies almost exactly in the latitude of Naples, the other vestiges of igneous action which Spain affords, occurring as they do in Murcia, are placed nearly parallel to Mount Etna.

Almazarron near Carthagena bears the strongest marks of having been the scene of volcanic action*. Here masses of trachyte and of volcanic conglomerate form a bold *cerro* of considerable height; and the curious aluminiferous rock of St. Christobal, which has been wrought for many ages, is derived from the decomposition of the former. These are associated with a porphyritic rock of a blood-red colour, with primary slates, and with a recent marine formation lying inland of it.

To the west is a vast mass of trachyte followed by more recent beds, and interrupted by a bold and lofty chain of primary rocks, called the Lomo di Vaca (*cow's back*). It may be remarked, that in this district occurred in 1829 an earthquake which did great damage in Murcia. Carthagena was in part demolished, and many neighbouring towns suffered severely, but the centre of the shock was near Orihuela. The town of Torre Viejo was entirely destroyed with a great loss of life, and the course of the river Sigura was said to have been changed.

Further south from the promontory of Capo di Gaieta, a great trachytic formation extends upwards along the coast to within a league of Carboneras.

I am not acquainted with any description of this district, except a short one contained in the second volume of the 'Anales de Minas,' published at Madrid.

From this it appears, that felspathic trachyte of great compactness and prismatic structure forms most of the high ground overlooking the coast. It is covered however by a rock containing augite and crystals of olivine, and in one spot, called Le Morron de los Genoveses, is a little hillock only 100 yards in height, washed by the sea except in one part, which is covered with pumice and tuff containing glassy lavas imbedded, and having a regular crater on its summit.

* See Captain Cook's (Widdrington's) Sketches in Spain, p. 323.

From this crater a lava-current of a semivitreous cellular aspect has descended, and has moulded itself upon the surface of the subjacent basaltic rocks.

In another part these volcanic rocks appear to be covered by a bed of Pectens, Ostreæ, and Madrepores, upon which again rests a trachytic or basaltic breccia.

Besides this series of volcanic rocks in the direction of the coast, there appears to be at a distance of about five leagues inland, and separated from the above by a chain of primary hills called the Sierra Cabrera, another little chain of low hills also volcanic, from one of which, the hill of the Sanctuary of the Virgin of the Cabeza, a current of lava has proceeded from an evident volcanic crater.

Such then are the volcanic appearances hitherto recognised on the eastern flank of the Peninsula; but I must not forget to notice the rocks called the Columbretes *, situated near the Spanish coast, about thirty-five miles to the eastward of the limestone range which separates the alluvial plains of Valencia and Tortosa. From the chart given by Captain Smyth, it would appear that the larger island exhibits all the indications of being a volcanic crater, broken away on its eastern side, and the rock of which it consists is of trachyte, covered by ejections of scoriæ, obsidian, and lavas of various kinds. It would probably be regarded by Von Buch as a crater of elevation, like Santorino hereafter to be described. Another of the rocks consists of clinkstone, and all the rest are volcanic. Captain Smyth regards the larger island, from the analogy of the name Columbretes, as the *Ophiusa* of the ancients.

Let us now proceed to point out briefly, what has been discovered with reference to the subject-matter of this volume on the western side of the Peninsula.

The notoriety which the great earthquake of Lisbon in 1755 has obtained is calculated to create a general expectation, that many traces of volcanos would be found in the immediate neighbourhood of that city. But it appears, by the most recent and authentic account of the geological struc-

* See Captain Smyth's account of them in vol. i. of the 'Geographical Journal.'

ture of that locality which has come to my knowledge*, that although an immense sheet of basalt extends from Santa Catherina on the Tagus to Bucellas, a distance of nearly twenty miles, and although many of the hills around Oeiras, near the mouth of the Tagus, are capped by masses of the same rock, still, that the whole of it was thrown up before the deposition of the oldest of the tertiary formations, and consequently, as indeed its own texture would indicate, is submarine.

The liability to earthquakes therefore, to which Lisbon appears subject, would seem to arise from the want of a volcanic vent, and the frequency of thermal waters throughout most parts of Portugal would favour the idea, that volcanic action may be going on in many other parts of this country in a more subdued manner.

Dolomieu notices in the province of Beira a mountain called Sierra de l'Estrella, the Mons Herminius of the ancients, which he says is very lofty, possesses a conical form, and emits a hollow sound when trod upon, as if it contained caverns. He states, that there is a large excavation on its summit, having at its bottom a lake through which bubbles of air rise, and that at its base are columns of basalt. Whether from this rather vague statement we are to infer the existence of an extinct volcano in the above locality, must be left for future observations.

Maltbrun mentions, that the small chain which separates Portugal from the Spanish province of Algarve, and terminates in Cape St. Vincent, is divided into two ranges, the eastern called Sierra Calderona, the western Sierra di Monchiqua. On the eastern range lava and other substances of the same sort appear, so that the name of Sierra Calderona, or Caldron Mountains, is not inapplicable to the volcanic products here exhibited, for the craters still retain their forms and the characters that mark their origin. Cape St. Vincent is, I believe, volcanic.

* That published in the 'Geological Transactions' (vol. vi. new series) by Mr. Sharpe.

CHAPTER XVII.

VOLCANOS OF ICELAND.

Other indications of volcanic action on the confines of the Atlantic Ocean in parts appertaining to Europe—Ireland—Scotland—Hebrides—Faroe. Iceland.—The latter island particularly described—its general structure—direction of its active vents—classification of its volcanic products—cavernous lava.—Active volcanos—their number and position in the south of the island.—Eruption of 1785—1846.—Volcanos in the north.—Character of the Iceland lavas.—Sulphur mountains.—Geyser springs—their constituents—their high temperature.—Minerals of Iceland.—Surturbrand. Island of Jan Mayen.

In the preceding chapters, the volcanic phænomena which were brought before the notice of my readers existed for the most part in countries which had been visited by the author; so that although a large proportion of the facts related do not claim to be the result of original observation, yet it has at least been in my power in most cases to appreciate the value of the information, in consequence of having compared it with my own recollections of the region referred to.

In the remaining portions of my work I shall not have the same advantages, and accordingly, if the descriptions introduced are able to put forth, with any kind of justice, higher pretensions than those belonging to a mere compilation, they must derive them from that general familiarity with the subject, which may have enabled the author to select from the mass of materials before him the parts best calculated to enlighten us with regard to the real nature of the operations from which they arise, and not from any personal acquaintance possessed by him with the localities themselves.

In pointing out then the parts of Europe in which volcanic products exist, not yet brought before our notice, there will be a natural propriety in alluding first to those placed within the verge of that Ocean, the confines of which, in treating of Portugal, we had already reached; for although Ireland, the Hebrides, the Faroe Islands, and Iceland, are now separated one from the other, as well as from the Iberian Peninsula, by

vast tracts of sea, still the late researches of Professor Edward Forbes* have rendered it probable, that they were once connected by a continuous tract of land, ranging from the Azores, along the line of that belt of Gulf-weed which exists between the fifteenth and forty-fifth degrees of north latitude.

It is not my purpose however to treat of the geological structure of any portion either of Great Britain or of Ireland, first, because the details are already before the world in treatises readily accessible to the English public†, and secondly, because the volcanic products seem in these regions mostly submarine, and are apparently in no cases of more modern date than the age of the chalk.

In accordance indeed with this great antiquity, and with the almost total cessation of volcanic action in the country subsequently (unless indeed the slight earthquake-shocks perceived at Cumrie be allowed to establish the contrary), we observe throughout these districts an entire absence of thermal springs, as well as of those other minor exhibitions of igneous action, which occur in most other localities, where equally wide-spreading manifestations of the same forces have taken place.

It is true that many of the basalts which I have noticed as occurring in Germany were similarly circumstanced, if we may judge by their characters and structure, but then they are associated with other igneous products more nearly approaching in these respects to those produced under actual circumstances, and it would have been difficult to have described the latter without introducing some notice of the first.

In Ireland, on the other hand, as well as in the Hebrides, we have an example of volcanos, which during the whole of the extended period of time embraced within the tertiary epoch, no less than within the compass of historical times, have given no token of vitality—a circumstance, as it appears to me, more reconcilable with that theory which attri-

* Memoirs of the Geological Survey of Great Britain, vol. i.

† Macculloch's Western Islands—Jameson's Mineralogical Travels—Berger on the Geological Features of the North-Eastern counties of Ireland, with an Introduction and Remarks by the Rev. W. Conybeare—Descriptive Notes referring to an outline of Sections of the same Coast, by Messrs. Conybeare and Buckland, &c.

butes volcanic action to certain chemical processes taking place within the interior of the earth, than to the idea of its arising merely from the contraction of the crust upon its fluid contents, which latter being inexhaustible, ought, it should seem, according to this hypothesis, to be protruded periodically, and to afford a fountain of igneous matter as unfailing as the source from which it proceeded.

The same reasons for omission exist with respect to the Faroe Islands likewise, which consist, as it would appear, entirely of compact and amygdaloidal trap, neither of which can be referred to subaërial volcanos*.

The only rock which forms an exception to that igneous origin which we now are all agreed to ascribe to basaltic rocks, is the coal of the island of Suderoe, which, like that lately discovered in Kerguelen's Island, and the vein met with at Ballinty on the coast of Antrim, is imbedded in trap.

And with the idea that the whole had been erupted at the bottom of a deep sea and subsequently upheaved, the only fact at variance, seems to be the occurrence of an amygdaloid having its upper surface filled with small insulated perpendicular cavities, as if caused by the escape of a gaseous fluid whilst the rock was in a soft pasty condition—a fact analogous to what I have noticed in my account of the volcanic rocks near Frankfort (p. 105).

I shall proceed then to Iceland, where volcanic operations have been carried on on a more gigantic scale perhaps than in any other part of Europe; for although there be no one mountain in this island which rivals Mount Etna in magnitude and height, yet evidences of igneous action pervade a much larger area than in Sicily, and have generated in the course of time a much greater amount of volcanic products.

Indeed, whilst the utmost length of Sicily is about 100 miles from Messina to Cape Passero, and its breadth 150 from Messina to Trapani, Iceland measures at least 240 miles from its most northern to its most southern point, and as much from east to west; and whilst of the former island not a tenth of the surface is volcanic, the whole of the latter is

* Sir G. Mackenzie and Mr. Allan, Edinb. Phil. Trans. vol. vii.—Mr. Trevelyan, Edinb. Phil. Trans. vol. viii.

derived from igneous operations either of an early or of a recent date.

According to Krug von Nidda *, one of the latest geological travellers who have visited this island, the whole surface, embracing an area of 1800 square miles, presents only two principal rock-formations, one seeming to occupy the bottom of that northern ocean out of which the islands of Iceland and Faroe have risen, and consisting of trap rocks of the ordinary kind; whilst the other, which forms the nucleus of the former island, and may be regarded as the principal cause of its existence as an upraised tract of land, is trachyte, with its accompaniments of tuffs and lava currents. If, as Krug von Nidda thinks, there are any Neptunian beds in the island, they are at least so metamorphosed by the action of heat as to put on the characters of an indurated tuff or obsidian. The trachyte traverses the island in a broad band from S.W. to N.E., and has produced in the line of its elevation an immense fissure, along the sides of which the accompanying traps are seen to be upheaved.

Accordingly the active volcanos of Iceland are placed, if we believe this writer, on the borders of the above fissure, or at the junction of the trachyte with the trap.

The coasts of Iceland, as may be seen by the map, are intersected by deep gulfs, caused, as this geologist supposes, by that rupture of the strata which was brought about by the elevation of the trachyte and the contiguous trap. These gulfs, which are seldom more than half a mile in width, extend high up into the mountains flanked by precipitous and overhanging cliffs.

The arrangement of the beds of trap is always nearly parallel to the horizon, but there is a slight inclination towards the interior of the island, or towards the supposed trachytic nucleus. This, which is the very reverse of what might have been expected, is explained by the giving way of the older rock along the line of fracture.

Such is the view of the general structure of Iceland taken by the author above-quoted; but a more recent geologist, M. Robert, who accompanied the scientific expedition des-

* Karsten's Annalen, vol. ix., partly translated in Jameson's Journal for April 1837.

patched by the French Government to Iceland and Greenland, under the direction of M. Gaimard, disputes the general occurrence of trachyte throughout the island, and the linear arrangement represented as belonging to it, maintaining that in some instances M. Krug von Nidda has mistaken for trachyte some other rock, as at Smiorfäll, a lofty mountain which consists in reality not of trachyte, but of *basanites** and *mimosites* having a porphyritic character.

Be that as it may, there can be no doubt that Krug von Nidda is correct in assigning to the volcanic operations now proceeding in Iceland a direction from N.E. to S.W., bounded on the west by the course of the Huitaa, and extending from Faxifiord on the south to Eyafiord on the north, and having for its eastern boundary Orœfa-jökull and the valley of Langor Fleot to its termination in the sea on the coast in the province of Mulé Syssel.

Within this area all the volcanic action now going on in Iceland is circumscribed, whilst the country to the right and left of it consists of trap rocks indeed, but not of modern volcanic products.

We may therefore revert to the distinctions laid down many years ago by Sir George Mackenzie as substantially correct, there being nothing to controvert his views with respect to the existence in Iceland of two classes of volcanic products, submarine and terrestrial, although there may be reasons for differing from that writer as to the particular rocks which he has assigned to the one or to the other of these divisions.

Thus, whilst he refers the trap rocks which constitute so large a portion of the surface of Iceland to eruptions which had taken place under the pressure of the ocean, he distinguishes between the latter and those lavas which he calls submarine, but which appear to include many cellular and even vitreous rocks, such as pearlstones, pumices, and even obsidian.

Much as we are indebted to this author for the clear views he had the merit at this early period of promulgating with

* Basanite, according to Cordier's nomenclature, is a mixture of augite and felspar, with distinct crystals of augite imbedded. Mimosite is also a mixture of felspar, augite and titaniferous iron, with a granitic structure.

respect to the effects of pressure in modifying the condition of igneous products, we are left by him much in the dark as to the application of his principles to the particular rocks of Iceland.

Thus he mentions a curious description of lava, which, he says, constitutes an extensive stratum spreading over the surface of a level plain at the foot of Hecla, and presenting a succession of large bubbles or blisters, varying from a few feet to forty or fifty in diameter. It also contains numerous little craters, from which flames and scoriæ had issued, but no lava. These craters are often partially covered in by domes of the same material, as though the whole rock had been first softened by the operation of heat, and portions of it had then been made to swell outwards by the extrication of elastic vapours.

Our author has chosen to distinguish this variety by the name of *cavernous lava*, and supposes it to belong to the class of submarine products, as it dips under the sea, and is in many cases covered with alluvial sand.

The cellular character of the surface does not seem in accordance with this supposition; and although the compact and columnar structure of its internal portions may appear to favour it, yet it must be recollected that thick beds of lava which have flowed in the open air frequently assume these characters below a certain depth, and that the cavernous bed alluded to was ascertained by Sir George Mackenzie to extend to a distance of at least eighty or ninety feet beneath the surface.

It seems more probable therefore that it was one of those ancient currents which may have been poured forth from some orifice in the midst of a level plain, and have spread over its surface in all directions so as to form one wide and continuous flood of lava.

Its continuation under the sea would not be at variance with this idea, unless it can be traced into very deep water; nor do we know enough of the nature of the alluvial deposit superimposed to be able to draw any safe deductions from its presence.

I shall have to recur to the same kind of phænomenon when the island of Lancerote comes under our consideration

Iceland then exhibits proofs, not only of submarine eruptions, in the masses of greenstone, basalt, and clinkstone which are widely distributed, but also of igneous action, which, though not traceable to any volcanos now in activity, was produced either in the open air, or at least under shallow water. Such are the pumices, obsidians, and tuffs which are so abundant, as well as the cavernous lava above described.

But independently of these, we observe throughout this island indications of volcanic action under several of its different forms, proceeding with the greatest energy at the present day.

Iceland numbers no less than twenty active volcanos, if we allow ourselves to consider in that light all those mountains, from which eruptions of lava or scoriæ have emanated, at one time or other since it was first colonized in the ninth century after Christ.

Of these however eleven have had but one eruption, and amongst these four only occurred within the last century; whilst of the remaining nine, Myrdalls-jökull, Skaptar-jökull, Sandfells-jökull, Skeidarar-jökull, Reykianes, Hecla and Krabla alone would appear to be active at present; Trölladyngia having had no eruption since 1510; Orœfa-jökull none since 1362; and others having been for a nearly equal time in a state of quiescence.

It is evident that those regarded as active are only different vents for the same eruptive force, which manifests itself in the south of the island chiefly at Hecla, Eyafiall and Köttlugia; in the north at Krabla, Leyr-knukur, and Trölladyngia; and in the east at Orœfa-jökull.

Hecla indeed has been in a state of eruption no less than twenty-two times from the earliest recorded date, 1004 or 1005, to 1772, to which we must add an eruption in 1845, which appears to have done much damage.

The height of this mountain above the level of the sea is estimated at 4795 Paris feet. It is covered with obsidian, which is sometimes resinous, or passes into pitchstone, and sometimes into pumice. Mackenzie observed a stream of lava derived from this mountain which consisted wholly of obsidian.

Eyafialla-jökull was in a state of eruption in 1822. It is

covered with eternal snow, and reaches a height of 5500 feet.

Orœfa-jökull, in the east of the island, is somewhat more elevated, and may be set down as the loftiest point in the island.

The most formidable eruption that has taken place in modern times was in the year 1783, when Skaptar-jökull for the first time since the memory of man poured forth two large streams of lava. Previously to this occurrence flames had burst forth from the sea at a distance of five German miles from Cape Reykianes, and a new island had risen to the surface, which however within a year afterwards disappeared. It is stated that at one place there was more than 100 fathoms of water, half a mile from the island. About the same time a submarine eruption took place seventy miles from the same cape, which is said to have thrown up pumice enough to cover the sea for a space of 150 miles round.

It is also stated that a new island appeared opposite Hecla in the year 1563*; but as to this latter fact, there are some doubts. A great eruption of Mount Hecla, of which however no authentic accounts appear to have reached this country, took place in the year 1845, one consequence of which was of the same kind as that which resulted from the one just noticed as occurring in 1783, namely the destruction of numbers of cattle owing to the deleterious effects arising from the quantity of volcanic dust and scoriæ†, which covered the face of the country, and mixed both with the herbage and the water of the ponds and streams. In the last instance the cattle are said to have suffered from an exostosis of the extremities; but in the former it seems more probable that deficient nourishment, arising from the cause assigned, brought with it a train of disorders of a different kind. Indeed, not only had the food become indigestible by its admixture with

* Raspe de Novis Insulis, p. 126.

† On the 2nd September 1845, the day of the eruption of Hecla, a Danish vessel near the Orkney Islands, at a distance of 115 Danish miles (about 500 English) from the volcano, was covered with ashes, which, when examined by a microscope, was found to resemble pumice, but was intermixed with organic bodies, as was the case with that which fell on Iceland itself. Ehrenberg discovered in both cases infusoria.

a material of so harsh and irritating a quality, but the teeth of the cattle are stated to have been worn away, and their power of browsing upon the herbage consequently impaired.

When it is mentioned, that in 1783 the atmosphere throughout the whole of the island was obscured, for months after the eruption had taken place, by the enormous quantities of fine dust suspended in it, and that traces of the same were perceived even so far off as Holland, we need not wonder that the whole face of the country in the neighbourhood of the volcano should be so covered with the same, as to be no less injurious to vegetation than pernicious to animal life.

Since the eruption of 1845, the island has been visited by several French and German geologists.

One of these, M. Descloizeaux, who was in company with Professor Bunsen of Marburg, mentions a change in the height of the mountain, indicating a falling-in of a portion of the summit. From his measurements, it would appear that the height of the loftiest part of the cone is not less than 500 feet less than it was in the time of Sir G. Mackenzie; and the form of the crater has also changed.

The exterior part of the present cone M. Descloizeaux describes, as traversed by fissures containing fumaroles which deposit sulphur; and as the bottom of the crater was covered with old mud, it was clear that the eruption of 1845 was not from the main crater, but, like the more recent ones of Etna, from the side of the mountain.

From the place where the eruption broke forth, to its termination in the plain below, he calculates its length at nearly ten English miles; its thickness from forty-nine to eighty-two feet,—an enormous mass, though less than that emitted from Skaptar-jökull in 1783. Th inclination of the stream varied from 0° to 25°; but, in conformity with the observations of Dufrenoy, it was found that the lava-stream was made up of a number of isolated blocks, the congeries resembling an immense ribbon, at the edges of which is a *talus* highly inclined, and the interior much-fissured*.

Whilst the volcanos in the south of the island have shown signs of vitality from the earlier times, Krabla in its northern extremity first became known as an active vent in the year

* Horner's Address for 1847.

1724, since which period it has had four eruptions, one of which produced a stream of lava no less than four miles and a half in width, and nine in length.

M. Robert nevertheless states that Krabla itself is nothing more than a solfatara, and that the lava has always proceeded from certain spots in its neighbourhood, or at its base.

It must be remarked, that since the period at which Krabla has been in activity, neither Leyr-knukur nor Trölladyngia has had an eruption.

All the lavas ejected from the Iceland volcanos appear to be of a felspathic character, a circumstance tending to confirm Krug von Nidda's view of the internal constitution of that range. We have already noticed the current of obsidian at Hecla, and in like manner a large mass of the same material and of pumice has been observed at Krabla.

But the volcanic action going on underneath this island is indicated, not only in the manner already alluded to, namely in eruptions of lava and scoriæ, but likewise in the exhalation of sulphureous vapours, as in the mountains of Krisuvik described by Sir George Mackenzie (p. 115).

These present in some respects analogies to the pseudo-volcanic phænomena of Macaluba in Sicily, and in others to those of a genuine volcano, in continual but languid action.

The rock consists of alternating beds of white clay and sulphur, from all parts of which steam is given out. This was remarkably the case in a deep hollow into which the author descended, where a confused noise was heard of boiling and splashing, joined to the roaring of steam escaping from narrow crevices. At the bottom of this hollow was a caldron of boiling mud about fifteen feet in diameter. There was a constant sublimation of sulphur, which formed beautiful crystals round the sides of the cavity.

It is stated by Krug von Nidda, that sulphuretted hydrogen is the prevailing gas evolved from these springs, and we have thus an ocular proof of the manner in which sulphur has been deposited in the parallel case of Sicily, where the vastness of the quantity accumulated is an index of the enormous volume of hydrogen disengaged from the volcano.

At the other extremity of the great longitudinal valley

which is the theatre of these remarkable igneous operations, near the volcano of Krabla, and north of the Myvatn Lake, are sulphur mountains of a still more considerable extent, described by Henderson. The phænomena they exhibit are mostly of the same character.

The celebrated springs of Geyser are, however, the phænomena which most forcibly arrest the attention of the traveller in this country. The two principal ones are, the Great Geyser, and the Strokr or Strokkuss. The first is an intermitting fountain, which ejects vast columns of steam and water to a great height, at intervals varying from twenty-four to thirty hours, and produces smaller discharges of the same every two hours; the second is both intermittent and permanent, producing a gigantic eruption every two or three days, but being in the meantime in a state of constant agitation and boiling. The intermitting character of these fountains may be, in some measure, imitated, by pouring a stream of water through a bent tube depressed about the centre, and heated in that part alone, under which circumstances the steam suddenly generated at the bottom will force one portion of the water out in a jet from the opposite extremity to that at which it entered, driving back at the same time the current of water that continued to flow in. In this manner the water might be propelled in jerks, as happens in the case of the Geyser springs.

Such an explanation however is far from being adequate to account for the complicated phænomena of these fountains, which, after a pause of so many hours, first threw up water, and afterwards vast columns of steam, to the height sometimes of 200 feet, and then immediately sunk into a temporary repose; neither is it applicable to the singular circumstance mentioned by Mr. Henderson, as to the possibility of bringing on the explosion at any given time by merely throwing large stones into the orifice. The latter fact indeed seems to prove that the generation of steam is constant, and that nature has provided other vents sufficient to carry off a certain portion of the elastic vapour, unless when obstructed in the manner produced by Mr. Henderson, in which case its rapid accumulation gives rise to an almost immediate explo-

sion. In the same manner we may explain the peculiarity of the Strokr; namely, by supposing a part of the steam generated to be constantly escaping, whilst another portion is arrested in cavities where it goes on accumulating.

The presence of siliceous earth in the waters of the Geyser springs has attracted much attention; but, like all other natural phænomena, it turns out, when investigated, to be by no means an isolated fact, but to be common, in greater or less degree, to all natural springs possessing a high temperature. Silex, it is well known, exists in two forms, one of which is soluble, the other insoluble in water. When liberated from its combination with an alkali or an earth, which takes place when hot water impregnated with carbonic acid acts upon a felspathic mineral, it is probably in the former condition, and is therefore retained by the water in solution until after it has reached the surface. Its continuance in this condition is assisted probably by the presence of free alkali in the Geyser water, as was ascertained by Dr. Faraday in a sample sent him by Mr. Barrow, and indeed had been announced long ago by Dr. Black; but the largeness of the quantity present, in which respect the Geyser springs appear to surpass all other known thermal waters, may be connected with the high temperature which the water in them appears to attain before it is ejected.

According to Monsieur Robert, a thermometer let down into the tubular aperture through which the water of the Great Geyser reaches the surface, rose at a depth of 30 feet to 219° of Fahr., and at 60 to 255°, which, if arising from the pressure exercised, would indicate one exceeding two atmospheres and a half*. But some recent researches of M. Donné seem to show that water entirely divested of air may attain this high temperature before it enters into ebullition, and it is possible that this may supply us with the true explanation of the

* This has been confirmed by the more recent observations of MM. Descloizeaux and Bunsen made in July 1846. See Comptes Rendus.

Great Geyser—depth of canal 22 metres; temp. of the bottom from 122°·5 to 127°·5 cent.

Metres.		
9·50	above the bottom	121°·1
14·75	„ „	from 106°·4 to 110°·0
19·55	„ „	„ 84°·7 to 85°·2

Strokkur at the bottom, depth 13·55 metres; temp. 113° cent. to 115°.

phænomenon. The quantity of silica present in these waters causes a deposition round the mouths of these springs similar to those calcareous incrustations so common in other localities, producing a bed of siliceous sinter several feet in thickness*.

Almost the only substance not connected with volcanic operations which occurs in Iceland is the *surturbrand* or bituminous wood, of the situation of which the intelligent missionary, Mr. Henderson, has given us a detailed account. The west side of a perpendicular cleft in the side of a mountain called Hagafiall exposes a section of ten or twelve horizontal strata, of which the surturbrand is undermost, occupying four layers, which are separated from each other by intermediate beds of soft sandstone and clay.

They vary in thickness from a foot and a half to three feet, and differ also in quality, the two lowest strata exhibiting the most perfect specimens of mineralized wood, free from all foreign admixture and of a jet-black, the numerous knots, roots, &c. leaving no doubt of its vegetable origin. The two upper strata contain an admixture of earthy and ferruginous matters, and in the midst of them occurs a thin layer, four inches in thickness, consisting of a schistous mass which appears to be made up entirely of leaves closely pressed together, separated only by a little clay. These leaves are chiefly of poplar, a tree, Mr. Henderson says, at present not met with on the island. The beds of surturbrand support an alterna-

* If we were to credit the accounts given by some travellers, we must attribute still more extraordinary effects to the water of these Geysers than the mere solution of silica. In the second volume of the Edinburgh Philosophical Journal may be seen an account of Iceland, by Menge, a German mineralogist, in which he attributes to these springs the formation not only of siliceous sinter, but even in many instances of tuff, of basalt, of porphyry, and of obsidian. He even declares that he saw one hot-spring producing lava, another forming basalt, and a third trap-porphyry, and notices a particular case where he extracted from a boiling marsh a muddy hot mass, which when broken exhibited the characters of basaltic lava in the centre, and towards the surface passed gradually into red and grey mud. Such extraordinary facts however require for their belief the very best evidence, and I fear the testimony of Menge will hardly be considered sufficient to substantiate them. That purely siliceous minerals, such as pearlstone, hyalite and opal, may be the productions of hot-springs is indeed less improbable, but all analogy is opposed to the idea that extensive strata of basalt or porphyry have ever been produced in the same manner.

tion of basalt, tuff and lava, which extend to the summit of the hill.

As to the beautiful specimens of double refracting calcareous spar which are obtained from Iceland, M. Robert appears to have ascertained that they are derived from an extensive vein penetrating a rock of mimosite at Eski-fiordur in the eastern portion of the island. It would appear indeed, that all the fine zeolites and other minerals for which Iceland is so celebrated are derived from the older or submarine volcanic rocks, and not from the lavas that have been ejected in modern times, a circumstance which I shall attempt to explain in a subsequent part of this volume.

Professor Bunsen of Marburg, in a recent memoir, states that Baron Waltershausen, who, after a residence of several years in Sicily, is now prosecuting his geological researches in Iceland, has discovered in both these volcanic islands a new mineral, called by him Palagonite, of which the tuff is principally made up. It is quite amorphous, with an uneven, small, conchoidal fracture, brittle, with about the hardness of apatite, in thin pieces, transparent, with a waxy lustre, by reflected light, brown, like coffee—by transmitted, honey-yellow*. It is full of infusoria, and hence Bunsen conceives it to be produced by the action of thermal waters. Darwin (Volc. Islands, p. 98) has noticed a similar substance in Chatham Island.

The only other volcano in the north of Europe is that in the island of Jan Mayen, off the coast of Greenland. This, when visited by Captain Scoresby† in the year 1817, exhibited the marks of a recent eruption, and was found to consist of cellular lava, of tuff, and of scoriæ; on its summit was a magnificent crater 500 feet in depth, and about 2000 in diameter.

Its principal mountain, the Beerenburg, rises to the height of 6448 Paris feet, surpassing every one of the Iceland volcanos. It is remarkable that it lies exactly parallel to the line of that great valley in which all the active volcanos of the latter country are situated, so that it would seem to be a prolongation of the same band of igneous operations.

* Its formula is $\dot{R}^3 \dddot{S}^2 + 2\,\dddot{R}\,\underline{\dddot{R}}\,\dddot{Si} + 9\,\underline{H}$, or Scapolite $+ 9\,\underline{H}$.

† Edinb. Phil. Journ.

List of Volcanos in Iceland which have been in activity since the is'and was first colonized, with the date of their respective eruptions.

[From Garlieb. Island rucksichtlich seiner Vulkans, &c. Freyberg, 1819, with additions.]

9th Century. 800 to 900.					Eldborgar-Hraun, about 850 A.D.		
10th Century. 900 to 1000.	Kötlugia. 900.						
11th Century. 1000 to 1100.				Hecla. 1004. 1029.		Thurra-Hraun. 1000.	
12th Century. 1100 to 1200.			Trölladyngia. 1150. 1188.	1104 or 5. 1113. 1157 or 8.			
13th Century. 1200 to 1300.	1245. 1262.	Reykianes. 1222. 1223. 1226. 1237. 1240.		1204 or 6. 1222. 1294.	Nes-Hreppar. 1219.		
14th Century. 1300 to 1400.		1340.	1359.	1340. 1374. 1390.	Öræfa-jökull. 1332. 1362.	Thormarkar-jökull, 1300 to 1350. Jökull near Mosfell, 1340. Raudikambur, 1311. Breidamarkar-jökull, 1362.	Herdabreid. 1340.

15th Century. 1400 to 1500.	1416.	1422.	1475.	1436.			
16th Century. 1500 to 1600.		1583.	1510.	1510. 1554. 1583.			1510. Thringvalla-Hraun. 1587.
17th Century. 1600 to 1700.	1625. 1660.			1619. 1625. 1636. 1693.			
18th Century. 1700 to 1800.	1721. 1755.	1783.	Krabla. 1724. 1725. 1727. 1729. 1730. Skaptar-jökull. 1783.	1728. 1754. 1766. 1772.	1727. Sandfells-jökull. 1748. 1749. 1750. 1751. 1752.	Skeidarar-jökull. 1725. 1727. 1728. 1753. Hofs-jökull. 1716. Hithoel. 1725. Reikjahlid. 1728.	Leyr-knukur. 1728. 1729. Hrossadels-Hraun. 1728. Eyafialla-jökull. 1717.
19th Century.	1823.	1824.		1845.			1821.

CHAPTER XVIII.

GRECIAN ARCHIPELAGO.

Rhodes and Delos not volcanic.—Santorino and the adjoining islands—accounts of ancient writers—islands thrown up in modern times—how formed according to Von Buch and others—Polycandro—Milo—Argentiere—Poros.—Promontory of Methana—accounts of its upheavement given by the ancients—structure according to modern geologists.—Ægina—Eubœa—Cerigo—Albania—Megalopolis in Arcadia—Mount Parnassus.—Zante, bitumen springs.—Cephalonia, curious phænomena.—Melida, subterranean noises.—Thermopylæ—Promontory of Mount Athos—Upper Mœsia—Servia—Macedonia—Thrace—Bosphorus.—Islands off the coast of Thrace—Lemnos—Imbros—Tenedos.

The accounts of ancient writers might prepare us to find indications of igneous action presenting themselves in many parts of the Grecian Archipelago.

It is true however, that in some cases modern observations have not confirmed the correctness of the reports handed down to us from antiquity. Thus the island of Delos, which the poets describe as of recent origin, is, on the contrary, almost entirely composed of granitic materials.

The island of Rhodes too, the supposed elevation of which from the bosom of the ocean Pliny records, in a manner which would lead us to infer the agency of volcanic forces, is composed, according to modern geologists, in a great degree of plutonic and neptunian rocks, and although basalt and trachyte also occur, yet they do not appear to be of recent date*.

Not far from it however is the little island of Nisyros†,

* See Mr. Spratt's account in the Proceedings of the Geological Society, vol. iii. p. 773, and Hamilton and Strickland, Geol. Trans. vol. vi.

Professor E. Forbes remarks, in some notes with which he has favoured me relating to various points treated of in this chapter,—"The great and conspicuous beds of marine tertiaries full of shells closely resembling existing ones, around the city of Rhodes, might have given rise to the ancient notion of the island having risen from the sea."

† Strabo, lib. x. p. 714, ed. Falc.

which Humboldt* infers, from the description of it given by a late traveller, Dr. Ross†, to have been actually upheaved, and to present an exact counterpart to the island of Palma, which Von Buch has particularly noticed, and which will come before us in a subsequent part of this work.

Dr. Ross however remarks, that the island conveyed to his mind the impression of being the gradual growth of volcanic operations, which accumulated large masses of igneous products, until the centre fell in and produced a deep circular cavity, whilst the outer rim of its base still stands encircling the internal cavity. Supposing a peak to have once existed, it must have been 4000 or 5000 feet high, for the brim of the present crater is more than 2000.

Several small outlying hills are scattered round the flanks of the volcano, which appear to be lava-streams, traceable to the centre of the island. But these have been covered by showers of ashes and light pumice, which afford a nidus for plants, and render the surface capable of cultivation.

There are warm springs at the base of the mountain, having a temperature from 20° to 30° of Reaum. which were noticed by Strabo; and there are also fissures in the rocks from whence hot dry air destitute of smell exhales.

The central cavity itself is in its highest point 2271 feet above the sea. It forms a valley a league in length and half a league in breadth. The upper part is covered with vineyards, the lower is bare and white with sulphur. From the bottom sulphur is continually sublimed, and slight detonations are incessantly taking place, which after rain and the prevalence of westerly winds are audible from a distance. It was this noise perhaps which gave currency to the fable of the ancient Greeks, who, according to Strabo, imagined that the giant Polybotes was confined under the island, itself indeed a fragment of the neighbouring island of Cos, which Neptune had detached and hurled into the sea.

The sulphur is so abundant as to be collected as an article of commerce, and is occasionally exported to Smyrna. The following woodcut, taken from Dr. Ross's Travels, may serve

* Cosmos, vol. i.

† Reise auf den Griech. Inseln, Bd. ii.

to give an idea of the structure of the island, and of its elevation-crater as Humboldt considers it:—

Plan of the Island of Nisyros according to Dr. Ross.

a. Nisyros.
b. Argos.
c. Vineyards.
d. Pond impregnated with sulphur.
e. Hot-springs.

Another island represented by the Greeks as having been upraised from the bottom of the sea is Santorino with its appendages, and this we have indeed every reason to believe modified at least, if not produced, by volcanic operations of a comparatively recent date.

It stands at the eastern extremity of a line of trachytic rocks and islands*, by which it is in a manner connected with the promontory of Methana in Argolis, as to which latter a tradition has, as we shall see, been handed down to us, indicating the occurrence of a volcanic eruption in that quarter also within historical times.

The islands possessing this same structure, which lie betwixt Santorino and the coast of Argolis, are Polycandro, Milo, Argentiere, and near the coast of the Peloponnesus, at the entrance of the Gulf of Ægina, Poros. Beyond Methana, also, the island of Ægina is of the same composition. Several

* See Plate III. for the "Volcanic Band of the Greek Islands" according to Von Buch.

other detached rocks possessing a similar structure are scattered about in the neighbourhood of the islands above-mentioned.

Santorino, the most eastern of this range, is the one which has exhibited the most recent indications of volcanic activity. It is of a horse-shoe form, the space intervening between the horns of the crescent being partly occupied by two islands, now called Aspronesi and Therasia, whilst the bay inclosed within this series contains three small rocks or islets, namely Great Cammeni, New Cammeni, and Little Cammeni.

The relative position of these islands is indicated in the "Chart and Section of Santorino."

Now the island of Santorino, known by the ancients under the name of Thera, as well as the smaller one near it called Therasia, are mentioned by Pliny as having been thrown up by the sea, both which statements may have some foundation in fact, although mixed up with much inaccuracy of detail.

Thus, in speaking of the larger island Thera, the Roman naturalist sets down the time of its appearance as happening in the 135th Olympiad, or about 237 years B.C., a date quite inconsistent with the mention made of the island by Herodotus, who states that it was given by Cadmus to Membliares, one of his followers.

If this historian is to be depended on, we must likewise regard as a poetical fiction the account which Apollonius Rhodius has given of the sudden appearance of the island at the period of the return of the Argonautic expedition*.

Nevertheless it is possible, from the name Automate, self-produced, given to the island now called Aspronesi, and from the tradition as to a new island having been thrown up about three centuries before the Christian æra, that some convulsion took place, by which this and the neighbouring island of Therasia were severed from the larger one of Santorino or Thera, of which until that time they had constituted a part.

Without at present entering into the question, as to how

* ......*βωλον δε, θεοπροπιησιν ιανθεις*
ἡκεν ὑποβρυχιην, της δ' εκτοθι νησος αερθη
καλλιστη, παιδων ἱερη τροφος Ευφημοιο.—Argon. iv. 1755.

the crater-shaped cavity of which these two islands form the outer portion was produced, it seems probable that they were once continuous with the extremities of the island of Santorino, and that their present separation from the latter was occasioned by some subsequent convulsion.

It must be confessed however, that the origin of the larger islands dates from a period too remote to be determined with any certainty, but with regard to those included within the area which they embrace, we have somewhat better grounds on which to proceed.

Thus Pliny mentions, that 130 years after the date of the appearance, or rather the separation of Therasia, the island of Hiera was thrown up, a statement confirmed by Justin and Plutarch* as to the fact, though not as to the date, for these writers mention the appearance of Hiera as having occurred during the war between the Romans and Philip of Macedon; and if we adopt the date assigned by Justin†, which is that of the year in which the battle of Cynocephale was fought, we must fix it at 197 B.C., and substitute in the text of Pliny for the number cxxx, xxxx.

It is to this event that Seneca seems to refer, where he speaks of an island thrown up in the Ægean Sea by an accumulation of stones of various sizes piled one upon another:—

"Majorum nostrorum memoriâ, ut Posidonius tradit, cum insula in Ægeo mari surgeret, spumabat interdiu mare, et fumus ex alto ferebatur. Nam primum producebat ignem, non continuum, sed ex intervallis emicantem, fulminum more, quoties ardor inferiûs jacentis superum pondus evicerat. Deinde saxa revoluta, rupesque, partim illæsæ, partim exesæ, et in levitatem pumicis versæ; novissime cacumen montis emicuit. Postea altitudini adjectum et saxum illud in magnitudinem insulæ crevit."

All these authorities however concur in placing Hiera between Thera and Therasia; and as of the three islands in that

* Justin, lib. xxx. c. 4.—Plutarch, De Pythiæ Orac.

† Justin's words are: "Eodem anno inter Theramenem et Therasiam, medio utriusque ripæ et maris spatio, terræ motus fuit; in quo, cum admiratione navigantium, repente ex profundo cum calidis aquis insula emersit." (Lib. xxx. c. 4.)

predicament, two, New and Little Cammeni, are understood to have been produced in modern times, we must conclude that Hiera is the one now known by the name of Burnt Island or Great Cammeni.

Pliny also speaks of another phænomenon of the same kind as happening in his own time*, for he tells us that in the reign of Claudius, A.D. 46, a new island called Thia appeared near Thera. But as he mentions it as only two stadia distant from Hiera, it is possible that the island may have been joined to the latter by a subsequent revolution, as by that recorded to have taken place in the year 726, by which Hiera is said to have been greatly augmented in point of size.

In the centuries succeeding the latter epoch, other changes are noticed with respect to these islands, amongst which the production of a new rock, that of Little Cammeni, in 1573, was the most remarkable.

Thevenot mentions a great eruption of pumice as having taken place in the sea near Santorino in 1638, and Father Goree† in 1707 was eye-witness of the appearance of a new rock between Little and Great Cammeni, which increased in size so rapidly, that in less than a month it became half a mile in circumference, and had risen twenty or thirty feet above the level of the waters, constituting a third island which was called New Cammeni, a name which it still bears.

The following is an extract from the account he has transmitted to us of the circumstances attending this event:—

On the 23rd of May 1707, the commencement of a new island between Great and Little Cammeni was perceived from Scaro, and from all that side of Santorino. It was at first taken for the wreck of a ship, but those who visited the spot under that impression found that it was a mass of rocks which rose from the bottom of the water. Some, whose curiosity got the better of their fear, had the hardihood to land upon it, and found the surface covered with a white and very soft stone; but, what was very remarkable, a large quantity of fresh oysters, which are rarely seen about Santorino, were found adhering to the rock newly thrown up. Whilst in the act of collecting them, they were frightened away by feeling the ground shake violently.

* Plin. Hist. Nat. lib. ii. c. 89.

† See Philosophical Transactions, vols. xxvi. and xxvii.

Between this and the month of July the island was observed to grow gradually larger, for though many of the rocks which were added to it sunk again into the waters, a sufficient number remained to add considerably to its volume.

In July the appearances were more awful, as all at once there arose, at a distance of about sixty paces from the island already thrown up, a chain of black and calcined rocks, soon followed by a torrent of black smoke, which, from the odour that it spread around, from its effect on the natives in producing headache and vomiting, and from its blackening silver and copper vessels, seems to have consisted of sulphuretted hydrogen.

Some days afterwards the neighbouring waters grew hot, and many dead fish were thrown upon the shore. A frightful subterranean noise was at the same time heard, long streams of fire rose from the ground, and stones continued to be thrown out, until the rocks became joined to the White Island originally existing.

Showers of ashes and pumice extended over the sea, even to the coasts of Asia Minor and the Dardanelles, and destroyed all the productions of the earth in Santorino.

These and similar frightful appearances continued round the island for nearly a year, after which nothing remained of them but a dense smoke.

On the 15th of July, 1708, the same observer had the courage to attempt visiting the island, but when his boat approached within 500 paces of it, the boiling of the water deterred him from proceeding. He made another trial, but was driven back by a cloud of smoke and cinders that proceeded from the principal crater. This was followed by ejections of red-hot stones, from which he very narrowly escaped. The mariners remarked that the heat of the water had carried away all the pitch from their vessel.

During the ten subsequent years the volcanic action had given rise to several other eruptions, but the same reporter states that in 1712 all was quiet, and no other indication of the kind existed, excepting a quantity of sulphur and bitumen which floated on, without mixing with, the waters. Its circumference at that time was about four miles.

It is important, with reference to the natural history of volcanos, to remark that in this case, as in many others, the mountain appears to have been elevated before the crater existed, or gaseous matters were given out. According to Bourguignon, smoke was not observed till twenty-six days after the appearance of the raised rocks.

Nor have these creations of igneous agencies even yet

ceased, for we find that a fresh bank of rocks is now in the very act of forming between the island of Little Cammeni and Santorino.

At the end of the last century it was stated by Olivier, that the bottom of the sea had been observed by the fishermen to have been considerably raised within a short period in this spot, so that the depth was no more than fifteen or twenty braccie (thirty or forty feet). In July 1829, M. Lalande sounded the reef, and found the depth not more than nine feet over an area of 2400 feet by 1500, gradually sinking down on all sides from the centre. The same spot, when visited by Bory St. Vincent on the 15th of September in the same year, was found to be still higher by two feet, so that in the course of a short time it will form a new island.

Now Santorino and its appendages are amongst the spots most confidently appealed to by Von Buch in favour of his theory of elevation-craters.

The abrupt escarpments on the side which looks towards the bay of that island, and of Aspronesi and Therasia, which together serve to complete the amphitheatre, are, according to him, the sides of a vast crater of elevation. The alternate beds of trachytic conglomerate and of tuff, of which this crater consists, all dipping outwardly from the centre at a considerable angle, were originally formed under the sea, and subsequently upraised, together with the mountain of St. Elias and the others, which consist, as we have seen, of limestone. The identity of composition existing between the islands of Therasia and Aspronesi proves, that they were formed at the same time with Santorino itself.

The three small islands subsequently produced within the area inclosed by the larger ones above-mentioned, may be regarded as due to the abortive efforts of the subterranean forces to establish a constant communication with the external air, and thus to constitute a volcano; but none such exists, for these rocks are all destitute of craters, and have only occasionally disengaged vapours and pumice. They are formed of a brown trachyte, sometimes resembling pitchstone, in which are dispersed crystals of glassy felspar.

Without entering here into the general consideration of Von Buch's views, I will merely state, as a particular objec-

tion alleged against its applicability to the case of Santorino, the absence of those deep longitudinal valleys, which, as theory suggests, ought to be produced, wherever a horizontal mass of rock has been elevated into a dome-shaped form.

It is admitted, that the spaces intervening between Santorino, Aspronesi, and Therasia might have been due to valleys formed in the manner which Von Buch's theory requires, but what, it is asked, has become of those which would be occasioned by the same forces, operating upon the opposite side of the former island?

Nevertheless, if we reject this theory, it does not seem easy to explain the formation of a volcanic crater in the midst of the sea in the only other way that can be supposed, namely by successive ejections of loose volcanic materials; and this difficulty must be met in the first instance, before we can be permitted to avail ourselves of the explanation proposed by M. Virlet, who suggests, that the hollow in the centre of the principal islands may have been occasioned by the falling-in of the materials which originally extended across from Santorino to Aspronesi and Therasia.

At all events, be the crater itself produced by elevation or not, it cannot be questioned that some of the minor islands, as well as the reef now in the act of forming, have been upheaved bodily by volcanic forces, for the island of Little Cammeni, observed by Goree, was certainly not made up of a mere accumulation of ejected fragments, nor is there any evidence that such are accumulating under the bed of the sea in the bay at present, so as to account for the reef above alluded to*.

* The following valuable additions to our information respecting the island of Santorino have been obligingly furnished me by Professor E. Forbes:—

"I visited, in company with Lieut. Spratt, the great island and those of Neokaimeni and Microkaimeni. The aspect of the bay is that of a great crater filled with water, Thera and Therasia forming its walls, and the other islands being after-productions in its centre. We sounded with 250 fathoms of line in the middle of the bay between Therasia and the main islands, but got no bottom. Both these isles appear to be similarly formed of successive strata of volcanic ashes, which, being of the most vivid and variegated colours, present a striking contrast to the black and cindery aspect of the central isles. Neokaimeni, the last-formed island, is a great

The next island, Polycandro, is reported to consist of volcanic materials; after which comes Milo, long celebrated for its alum, which Pliny* mentions as the best that could in his time be obtained.

Von Buch imagined it to possess a crater-shaped cavity, like Santorino, but this Virlet, who appears to have visited the spot, contradicts.

The north-western portion of the island however consists of trachyte, heaved up anteriorly to the tertiary beds, which in part cover it.

These trachytic rocks are penetrated with aluminite and with sulphur, in consequence of the constant passage of sulphureous vapours through their substance.

The same alterations are produced in the clay-slates and other rocks of the island. The elevated temperature of the soil of Milo proves that it is still under the influence of volcanic operations; some of the caverns maintain a heat from 35° to 38° cent., and there are thermal waters in the island as high as 55° cent. The island is also famous for its millstones, which appear to consist of trachyte altered by the action of sulphureous vapours.

heap of obsidian and scoriæ. So also is the greater mass Microkaimeni, which rises up in a conical form, and has a cavity or crater. On one side of this island, however, a section is exposed, and cliffs of fine pumiceous ash appear stratified as in the greater islands. In the midst of this pumiceous ash is the elevated sea-bottom of which I have given a notice in my Report on the Invertebrata of the Ægean (see Brit. Assoc. Trans. for Cork).

"We were told that similar beds of shells are seen occasionally in the cliffs of Santorino itself.

"In the main island the volcanic strata abut against the limestone mass of Mount St. Elias, in such a way as to lead to the inference, that they were deposited in a sea-bottom in which the present mountain rose as a submarine mass of rock.

"The people at Santorino assured us that subterranean noises are not unfrequently heard, especially during calms and south winds, when, they say, the water of parts of the bay becomes of the colour of sulphur.

"My own impression is that this group of islands constitutes a crater of elevation, of which the outer ones are the remains of the walls, whilst the central group are of later origin, and consist partly of upheaved sea-bottoms and partly of erupted matter, erupted however beneath the surface of the water."

* Hist. Nat. lib. xxxv. c. 52.

Pumice and obsidian of various kinds are scattered over many parts of the island, and it is curious that here, as well as in the Phlegrean fields near Naples, noxious miasmata so abound, that the few inhabitants of this once-populous island are the very pictures of wretchedness and disease, insomuch that Choiseul Gouffier is disposed to attribute to the exhalations of the volcano what is probably to be sought for in some other and more occult cause*.

Argentiere, anciently called Cimoli, is probably connected with Milo in its structure as well as its situation. It has obtained its modern name from the silver-mines which were formerly worked there, but are now abandoned, and which probably lie in a trachytic conglomerate like those of Königsberg in Hungary. Indeed, like Milo, it is entirely vulcanised, being partly composed of trachyte, and partly of tertiary rocks altered by subterranean vapours†.

A curious modification of trachyte here occurs, which is at least analogous to the millstone-trachyte of Hungary, but which Virlet supposes to be a conglomerate, the particles of which have become reunited through the influence of the vapours by which they have been penetrated, so as to acquire the aspect and consistence of silex and even of jasper.

There is also found in the island a white heavy tasteless earth, called *Cimolite*, which forms an article of commerce, being much used in the Levant for cleaning woollen and other stuffs. It has a gritty feel, and effervesces, according to Tournefort, with acids, but this statement is not consistent with Klaproth's analysis‡. Pliny § calls it Creta Cimolia, and

* Prof. E. Forbes remarks: "The volcanic rocks of Milo have for the most part a much more ancient aspect than those at Santorino. The highest mountain (2500 feet) is trachytic."

† Prof. E. Forbes observes: "The appearances alluded to, of tertiary rocks changed, as if by volcanic vapours, and associated with jaspers, are seen not only in the volcanic but also in the non-volcanic isles. The fossiliferous tertiaries of Cerigo are in part of this nature. The fossils in such rocks are usually the larger bivalves (as Pectens) and Echinoderms."

‡

Silica	63·00
Alumina	23·00
Iron	1·25
Water	12·00

§ Hist. Nat. lib. xxxv. c. 18.

mentions its uses, one of which appears to have been its fitness to favour the generation of nitre*.

Olivier conceives that the Cimolian earth proceeds from the decomposition of trachyte, caused by sulphureous vapours, Virlet however regards it as belonging to the tertiary formation corresponding with the blue clay of Sicily and the Morea. It is met with in Milo, as well as at Argentiere†.

The island of Poros, situated on the coast of Argolis, consists of two rocks separated by an isthmus composed of sand. One of these rocks is of compact limestone, the other of trachyte, which latter seems to have been upheaved, and is covered at its base with trass or pumiceous conglomerate.

Just beyond Poros is the promontory of Methana, formerly called Methone, which would appear from Ovid to have been the seat of a volcanic eruption that created an entire mountain, just in the same manner as in the last century the mountain of Jorullo was elevated in the midst of the table-land of Mexico.

The description of Ovid is indeed applicable to both these events, as may be seen by comparing Humboldt's account, which will be given in a future chapter, with the following lines, in which the poet refers to the elevation of the promontory just mentioned :—

Est prope Pithæam tumulus Trœzena, sine ullis
Arduus arboribus, quondam planissima campi
Area, nunc tumulus ; nam (res horrenda relatu)
Vis fera ventorum, cæcis inclusa cavernis,
Exspirare aliqua cupiens, luctataque frustra
Liberiore frui cœlo, cum carcere rima
Nulla foret toto, nec pervia flatibus esset,
Extentam tumefecit humum ; ceu spiritus oris
Tendere vesicam solet, aut direpta bicornis
Terga capri. Tumor ille loci permansit ; et alti
Collis habet speciem, longoque induruit ævo.

Metamorph. lib. xv.

---

* See a note on the passage in Strabo, lib. x., in which the island of Cimolus is mentioned.—Falconer's edition, vol. ii. p. 707.

† Prof. E. Forbes states : "Argentiere exactly resembles Milo in structure. I fancied the Cimolian earth was of volcanic origin."

It is probable that Strabo* may allude to the same event, where he speaks of a tract of land seven stadia high, being elevated round about Methone, owing to some exhalation of an igneous nature, for these two places are so near to each other that they might very readily be confounded.

Diodorus Siculus† relates, that Phædra, when enamoured of Hippolytus, consecrated a temple to Venus upon the Acropolis of Athens, from whence she could distinguish Trœzene, the residence of the object of her passion.

Now Dodwell remarks, "that the promontory of Methone, which at present obstructs the view, not only of Athens, but of its loftiest mountains, might possibly in the time of Phædra have been a flat surface, or not even have existed at all, as the whole of that at present mountainous tract has evidently been thrown up by the powerful operation of a volcano, which, according to Pausanias, happened in the time of Antigonus. Were the promontory removed, Athens might be seen over the northern extremity of Ægina."

It would appear from Strabo that even in his time the rage of the volcano was not exhausted, for he says that the mountain became sometimes inaccessible, from the intensity of the heat which it occasioned, and the sulphureous odour which it diffused, adding that it was visible at night from afar, and that the sea was hot for five stadia around.

Let us now see how these statements are borne out by the observations of those geological travellers who have lately visited the Morea.

The peninsula of Methana, says Virlet, is composed of a mass of hills attaining the height of 741 metres (more than 2200 feet) above the sea. The enormous dome thus constituted, which is nearly circular and covered with irregular crests of rock, belongs almost entirely to the trachytic formation. It joins on at its south to a small mass of compact greyish limestone containing Hippurites and other cretaceous fossils, and seems to have been thrown up at several distinct epochs, so that whilst one part of it was anterior even to the

* Ed. Falc. vol. i. p. 87.

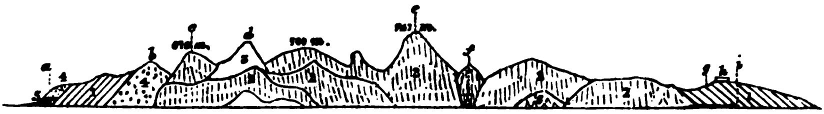
† Ἱδρυσατο ἱερον Αφροδιτης παρα την Ακροπολιν, ὁθεν ην καθοραν την Τροιζηνα.—Book iv. c. 62.

tertiary rocks in its neighbourhood, other portions seem to have been produced in historical times. The particular act of upheaval, which is noticed by ancient writers, he supposes to have taken place at the western point of the peninsula on a spot which is now called Kaymmeni-petra (burnt stones), on account of the black scoriaceous aspect of the trachyte of which it consists bearing some resemblance to that of the islands of Cammeni near Santorino.

The height of seven stadia (875 geometrical paces), which Strabo assigns to the new mountain, agrees very nearly with that attained by the culminating point of the present Methana. It seems probable that the warm springs alluded to by Pausanias, which first appeared in the reign of king Antigonus, preceded by an evolution of flames, still exist near the village of Vromo-lymni, opposite to the island of Poros. They have a temperature of 37° cent. and are impregnated with sulphuretted hydrogen gas. The rocks before Methana, in the mouth of the bay, were called the islets of Pelops. They are nine in number, produced, it is probable, by the volcano, and at one time bare. Some shrubs grew upon them when Chandler visited the spot *.

The annexed woodcut presents a section of the rocks forming the peninsula from north-west to south-east:—

Section of the Peninsula of Methana from N.W. to S.E. by M. Boplaye.



1. Compact limestone
2. Trachyte
3. Altered trachyte
4. Trachytic conglomerate
5. Tertiary beds
6. Millstone trachyte

a. Thermal springs.
b. Kaimeni Khoza.
c. Mount Rkisa.
d. Peak of Cestimis.
e. Mount Khelidonia.
f. Methana.
g. Vromo-lymni.
h. Ancient Acropolis.
i. Thermal springs.

The island of Ægina, situated a little to the north-west of

* Travels in Greece, chap. i.

the peninsula of Methana, constitutes the extreme limit of the trachytic formation in that direction.

Many varieties of the rock are seen in this locality, one of which may be called domite from its resemblance to the rock of the Puy de Dôme. These trachytes are much altered by the action of vapours, and aluminite is in consequence generated in many parts. They are covered with trachytic tuffs and conglomerates.

These trachytes seem to be of three distinct epochs, the most recent probably being contemporaneous with the upheaval of the rock at Methana; the second, occurring in the midst of the tertiary period, which has produced a little dome-shaped mass in the centre of the island, consisting of trachytic conglomerates that alternate with the tertiary beds; and the third, the great mass of trachyte which is anterior to both.

Such then are the best-authenticated accounts of volcanic productions existing in the Grecian Archipelago*, but other places either in Greece, or its surrounding islands, are mentioned by ancient writers, in a manner which would lead us to suspect some phænomena of the same description to have manifested themselves within their knowledge.

Thus Strabo states, that in the Lelantine fields near Chalcis in Eubœa, now Negropont, an earthquake took place, which did not cease until a chasm opened in the earth, from whence a stream of *hot mud* was vomited forth. M. Virlet remarks, that the only traces of volcanic action he could discover in the island, were a sand similar to that which in other places had resulted from the decomposition of trachytic rocks, and the existence in the island of hot springs. Hobhouse also mentions a rock near Chalcis, which was rent from top to bottom with a huge chasm extending into the bowels of the mountain. These however are very vague indications of recent volcanos, and we may therefore perhaps set down† the

* "Patmos is a volcanic island, consisting of trachyte.

"Some of the islands opposite Cnidus are volcanic and of as recent an origin with Santorino. I failed in reaching them. In one sulphur is collected, and there are solfataras now smoking."—Prof. Forbes' MS. notes.

† Nevertheless it is to be observed that Strabo uses the same expression "πηλος" when speaking of the lava of Etna:—το ὑπερχυθεν της κορυφης

phænomena which Strabo records, as of the same nature as that of Macaluba in Sicily, and therefore connected very remotely, if at all, with operations truly bearing this character.

Of the other islands off the coast of the Morea, Cerigo, the ancient Cythera, is the only one that deserves to be alluded to. From an old notice in the 'Journal de Physique' it would seem, that shells are found there inclosed in stones having a volcanic appearance, perhaps a pumiceous conglomerate like that of Hungary, and Badia mentions a chain of volcanic hills traversing the island*. Holland however questions the accuracy of these reports†, and I am not aware of their having been confirmed by any later authority‡.

With regard to the continent of Greece, it would appear that we must go considerably north of Thessaly, before any large development of volcanic formations will meet our eye. It is true that Lord Byron, in his 'Childe Harolde,' speaks of the mountains of Albania as

> Nature's volcanic amphitheatre,
> Chimara's Alps,

adding in a note that the Chimariot mountains appear to be volcanic.

On examining however the accounts of more scientific travellers, I find nothing to countenance such an opinion, and the phænomenon which probably led to this mistake was an extrication of inflammable gases, which takes place on the Chimariot mountains, just as it does on the Apennines, between Bologna and Florence.

I have the authority of Dodwell for stating that such is the case at present; and that it was equally so in ancient times we learn, not only from several ancient writers, such as Strabo§,

πηλος εστι μελας ῥεων κατα της ορεινης· ειτα πηξιν λαβων, γινεται λιθος μυλιος.—Lib. vi. p. 388, ed. Falc.

* See Ali Bey's Travels, vol. i. p. 205.

† Holland's Travels, p. 44.

‡ Professor E. Forbes says, "We saw no volcanic rocks in Cerigo. The oldest rocks are slates and grey limestones, probably of the Scaglia formation. Cerigotto has very recently been upheaved in part."

§ Strabo, vii. 316; Pliny, ii. 106; Ælian, xiii. 16; Plutarch in Sylla, p. 468. See also the singular poem on the Hot-baths of Pythia, which will be afterwards alluded to, v. 40.

Pliny, Ælian, and Plutarch, who speak of the occurrence of a Nympheum on the coast of modern Albania near Apollonia, celebrated for the flames that rose continually from it, but likewise from the existence of a coin of the city of Apollonia, which represents on one side Apollo, and on the other three nymphs dancing round a fire.

This however is plainly connected with the Asphaltum, which is so abundant in the mountains of Albania*, especially near Selenitza, and probably has no reference to anything of a volcanic nature†.

Dr. Boué, in his work on Turkey, considers it to be derived from beds of mineral pitch, which he says occur in great abundance in the nummulitic limestone of Albania.

Megalopolis in Arcadia is said by Pliny to have a burning mountain near it, but it is difficult to pronounce whether anything more is meant by his description, than a flame emanating from the ground like that above-mentioned.

I am not aware of any notice with respect to it existing among modern travels.

Such likewise appears to have been the spontaneous fire (*αυτοματον πυρ*) that emanated from the summit of Mount Parnassus. It must be supposed to have proceeded from both its peaks, as the poets speak of the *δικορυφον σελας* of the sacred mountain ‡; and although some have interpreted these passages as alluding to the sacrificial fires that were so frequent, it seems more simple to imagine that some natural phænomenon of the kind alluded to really existed.

As however the mountain would seem, from the account of Dr. Clarke and other travellers, to consist wholly of compact limestone containing Entrochi and other organic remains, we cannot entertain the idea that the phænomenon itself was connected with any really volcanic cause, or was anything more than a disengagement of gas like that exhibited at the Pietra Mala on the Apennines, and in divers other localities.

* See Strabo, lib. vii. 458; Dion Cassius, Hist. iv.; and Holland's Travels in Albania.

† Professor E. Forbes says, "For similar phænomena with those of the Chimariot mountains, see the account of the Chimæra in Asia Minor, in Spratt's and my 'Lycia.'

‡ Phœnissæ, v. 225.

Possibly the springs of bitumen found in the island of Zante may be associated with the same beds as those before-mentioned in Albania, although Mr. Strickland considers them to be derived from a region of volcanic activity, which he conceives to underlie the entire group of the Ionian Islands*. The frequent earthquakes that occur there certainly seem to imply that nothing but a vent is wanting to give rise to genuine volcanic eruptions, and the remarkable subterranean noises, that are heard in the island of Melida off the coast of Dalmatia, are probably attributable to the same cause†.

There is also in the island of Cephalonia a remarkable phænomenon, which will be again referred to when we come to speak of the theory of volcanic operations. It consists in a constant rush of sea-water, in quantity sufficient to turn a mill, into a cleft in the limestone rock, where it is either absorbed in swallow-holes or disappears under the rocks. It can best be explained by supposing that the stream is conducted to subterranean fires, and that the earthquakes so common in the island are caused by the expansion of the gases generated by the action of their fires on the sea-water‡.

Dodwell conjectures that the mountains near the Pass of Thermopylæ are volcanic, but he produces no better evidence than the story of Hercules and Deianira's tunic. Later observations have shown, that the chasm of Mount Pindus, which terminates abruptly in that part, leaving only the narrow pass called Thermopylæ betwixt it and the sea, is composed of the older class of rocks, belonging to granite, gneiss, mica-slate and clay-slate, together with granular marbles, and, according to a recent traveller§, serpentine.

Another spot to which ancient writers might induce us to assign a volcanic origin is the peninsula of Chalcis, bordering on the Gulf of Salonica, and terminating in Cape Paillouri.

* Geol. Trans. vol. v. new series.

† It is stated in Jameson's Journal, April 1844, on the authority of the Gazzetta di Milano, that a new volcano broke out in this island in September 1843, but I do not know that this has been since authenticated.

‡ See Strickland in the Geol. Trans.

§ Fiedler, Reise durch Griechenland, 1841.

It was formerly called Pallene, and is mentioned by Apollodorus as one of the spots assigned by the poets as the birthplace of the Giants, one of whom, Alcyoneus, is said to have been thrust out of it by Hercules; and the Phlegrean fields, which in later times were placed either in the vicinity of Mount Etna or of Naples, appear anciently to have been fixed in this peninsula, for Heyne observes*, that by Phlegra and Pallene is meant the same country, the latter peninsula being remarkable for earthquakes and subterranean fires. The same commentator further observes, I know not on what authority, that the very aspect of this spot even at the present time proves the agency of earthquakes and subterranean fires; but I do not find this statement confirmed by modern travellers; on the contrary, Dr. Holland states that the peninsula is in part at least of primitive formation†, and this is confirmed by Virlet in his general view of the geological structure of continental Greece‡.

Dr. Boué however, in his elaborate work on European Turkey, informs us, that the trachytic formation is much developed in Upper Mœsia, in Servia, in Macedonia, and in Thrace.

In Northern Macedonia are three great trachytic groups, that of the mountains round Karatova, that between Nagoritsch and the plain of Strazin, and that between the upper

* See Heyne, Annot. in Apollod. p. 29, and his Dissert. de Theog. Hes. in Com. Gott. v. ii. p. 151.

† It may be as well to notice a passage of Lucretius relating to another part of the same country, by way of directing the attention of future travellers. Scaptesula, the spot alluded to, was near Abdera in Thrace:—

> Nonne vides, etiam terrâ quoque sulphur in ipsâ
> Gignier, et tetro concrescere odore bitumen?
> Denique ubi argenti venas aurique sequuntur
> Terraï penitus scrutantes abdita ferro,
> Qualeis exspirat *Scaptesula* subter odores?
>
> *Lucret.* lib. vi. v. 810.

Scaptesula was the place mentioned as belonging to Thucydides, in Cimon's 'Life,' but I am inclined to think that Lucretius alludes to sulphureous vapours arising rather from the metallic ores that occur there (of which Plutarch speaks) than from any volcanic appearances.

‡ Expédition Scientifique de Morée, p. 37.

valley of Egridere and that of Bistritza. The talc slate and tertiary beds appear to have been heaved up by the eruptions of trachyte, and to have been acted upon by vapours which have communicated to them a red tinge. Molar porphyry is met with, forming entire mountains near Karatova, and there appears to be the same difficulty here as in Hungary, as to distinguishing between the trachyte and the sienitic porphyry found in the same neighbourhood.

In the plain of Thrace trachyte forms a chain of hills, skirting the southern base of the Balkan, from Jenisagra to Aidos, and again further south at Karabounar, from which place they extend as far as Fered on the borders of the Ægean Sea. They thus connect themselves with the trachytic mountains that have been observed near Constantinople, and with those of the islands of Samothrace, of Lemnos and Tenedos, together with the rocks of the Troad. With regard to the former, viz. those near Constantinople on either side of the Thracian Bosphorus, Dr. Clarke in his Travels had noticed their igneous character; and General Andreossi, in his remarks on the Lithology of the Bosphorus, had given a more detailed account of the rocks of which they consist. The latest and best remarks however are those of Mr. Hugh Strickland in the Transactions of the Geological Society, vol. v. 2nd series*.

He states, that the igneous rocks of the Thracian Bosphorus protrude through beds of slate and limestone, which he ascertained by their imbedded fossils to be Silurian.

They consist of trachyte and trachytic conglomerates, which commence, on the Asiatic side at Kavak, extending thence to Yoom-bornou on the Black Sea, and on the European side at Buyukdere. The conglomerates consist chiefly of angular trachytic fragments imbedded in a tufaceous paste, and are occasionally intersected by dykes of clinkstone and basalt, which latter assumes at times a columnar form. In one place veins of chalcedony intersect the conglomerate, cutting indiscriminately through the tufaceous paste and the imbedded fragments.

The prevailing colour of these rocks is greenish, owing to

* See also a Notice by M. Verneuil in the Bull. de la Soc. Géol. de France, vol. vii. p. 268.

the presence of copper, which gave the name of Cyaneæ to the weather-beaten rocks of the Symplegades. The island of Princes, at the entrance of the Sea of Marmora, is of the same composition.

It would appear that the borders of the Black Sea chiefly consist of a breccia, formed partly of marine, and partly of freshwater shells, together with stalagmitical limestone, and bituminous wood in beds, connected probably with the trachytic rocks which occur on either side of the Thracian Bosphorus, or the volcanic formations existing, as it is said, on the islands of Tenedos, Imbros, Samothrace, and Lemnos, of which however I know of no detailed description.

Imbros indeed is mentioned by Dr. Sibthorpe as containing various pitchstones, porphyries, and other volcanic rocks; and with respect to Lemnos, the fable of Vulcan, who, when expelled from heaven, first alighted upon this spot, would lead us to suspect, either that some tradition prevailed among the Greeks as to the existence in it of volcanic phænomena*, or that the rocks themselves had a burnt and sterile aspect.

The latter is the manner in which the fable is explained by Galen†, and it appears from modern travellers that many parts of the island are covered with pumice and ashes‡.

Choiseul Gouffier however is of opinion that the volcano from whence these products were derived is now sunk in the sea, and that certain portions of it only may be recognized in some rocks near that island§.

Nevertheless Dr. Hunt||, who visited the island, though without any view to ascertaining its geological structure, cursorily remarks, "that the whole island bears the strongest marks of the effects of volcanic fire; the rocks in many places are like the burnt and vitrified scoriæ of furnaces."

* This seems to be alluded to, when Philoctetes calls upon Neoptolemus to put an end to his sufferings with the Lemnian fire that was rolling round him:—

τῳ Λημνιῳ τῳδ' ανακυκλουμενῳ πυρι
εμπρησον, ω γενναιε.—*Sophocles, Phil.* v. 800.

† Φαινεται γαρ ὁμοιοτατον κεκαυμενῳ κατα γε την χροαν, και δια το μηδεν εν αυτῳ φυεσθαι.—*Galen, περι ἁπλων φαρμακων,* lib. ix. c. 2.

‡ See Dr. Hunt's paper in Walpole's Turkey.

§ Vol. i. p. 79; vol. ii. p. 130.

|| Walpole's Travels, vol. ii. p. 56.

It is probable that the Lemnian earth, famous from time immemorial in the cure of diseases, may be nothing more than a decomposed condition of trachyte, since it is found to be associated with volcanic products, and would seem from analysis to consist of the same ingredients as that rock, united in proportions not very different*.

* If long-established belief be any test of truth, the Lemnian earth ought to rank with our most approved remedies; its reputation has remained unimpaired in spite of all changes of manners, government, and religion that have since occurred; it is collected with the same superstitious ceremonies by the Christian as by the Heathen priest, and is given credit for equal virtues when it has received the impress of the Grand Signor's signet, as it was of old when it had obtained the seal of the chief magistrate of the place; its estimation has survived the very volcano to which it owes its existence, and has continued without interruption from the time of Philoctetes to the present (Choiseul Gouffier, vol. ii.).

Yet on analysis it is found to consist merely of—

Silica	66·00
Alumina	14·50
Oxide of iron	6·00
Water	8·50
Soda	3·50

Lime and magnesia in inappreciable quantity. Its external characters are described in Phillips's Mineralogy.

CHAPTER XIX.

ASIA MINOR.

Volcanic phænomena near the Troas—near Smyrna—Fougues—Ritri—in the interior of Asia Minor—Catacecaumene.—Petrifying springs and Plutonium near the ancient Laodicea.—Traditions with respect to volcanic eruptions in Cilicia—Hassan Dagh—Mount Argæus.—Samos—Patmos—Chimæra in Lycia—Scandaroon.

On passing the Hellespont, traces of volcanos are soon observed surrounding the plain of ancient Troy*.

Near Œné we come upon masses of volcanic tuff succeeded by columns of clinkstone, and finally of trachyte. Not far from the town is an isolated knoll of basalt rising abruptly from the plain. Although the valley of Beyrametch, remarkable for its hot springs, is composed of the tertiary limestone of the Troad, yet various ranges of trap or basaltic rocks traverse it, derived from the great centre of ancient igneous action seen round Bairam, the ancient Asso, which is built upon a volcanic rock consisting of trachyte. At Mantoscia, about an hour's march from Asso, is a ruined castle on a hillock, which has all the appearance of an extinct volcano, and seems even to have given off from it a current of trachytic lava.

Thus it would appear that a range of volcanic rocks occurs near the coast, connected possibly with the trachytes which, according to Mr. Strickland, occur near Smyrna. These rocks, on the south side of the bay, were erupted subsequently to the deposition of a lacustrine limestone and marl which were deposited in a basin. They consequently are spread over the bed of the ancient lake, incumbent on the beds belonging to the lacustrine series in a broad horizontal sheet, in some places stratified. No subsequent eruption appears to have taken place in this locality.

On the north side of the bay a similar eruption of trachytic matter has overlaid the same lacustrine deposits, forming the

* See Webb on the Troad, in the Biblioteca Italiana.

western half of the range of Mount Sipylus, about 2000 feet above the sea.

On the coast, in lat. 38°·40′, near the little harbour of Fouges, the ancient Phocæa, porphyritic, trappean and trachytic rocks also predominate, overlaid by tufaceous and pumiceous sands, which have assumed the hard semivitreous character of the trachytic rocks themselves.

At Ritri also (lat. 38°·18), the ancient Erythræ, the old Acropolis is situated upon an insulated peak of red trachyte, which rises abruptly to the height of 200 or 300 feet; and although, like that about Smyrna, perfectly crystalline, it has the appearance of being stratified, and dips to the north.

Whether volcanic rocks occur in many other points further south along the coast is not as yet ascertained; but they have been discovered at Boudroom, the ancient Halicarnassus, in lat. 37°, in a lofty cone called Chefoot Kaleh, nearly 1000 feet high, which is composed of a reddish felspathic trachyte, and indeed all the intermediate hills between that spot and Boudroom consist of trachytic and pumiceous conglomerates.

Messrs. Hamilton and Strickland have traced a still more extended range of trachytic rocks running more in the interior of Asia Minor, but nearly parallel to the above, that is, stretching from the Sea of Marmora in a south-eastern direction to the river Hermus*.

They commence on the north side of the lake of Apollonia,

* They appear to have been first pointed out by Browne the African traveller, as appears from the following passage in the extracts from his journal published in Walpole's Travels in the East:—"My eyes have been very much opened in this journey to the volcanic nature of certain parts of Asia Minor and its confines. At Kôlah, near the Hermus, only three days from Smyrna, may be seen an unquestionable site of volcanic eruption. It is one of the most recent, though still probably of a very remote period. Carabignar is another, bnt this probably may have been noticed by others. Kôlah, I imagine, has not hitherto been observed. I shall have something to say of Afium Karahissar. The neighbourhood of Konié, and still more of Kaisarié, is overspread with fragments of lava, some of it almost in the state of scoriæ. The quantity of lava in the district of Erzerûm is immense, and the whole country about Mount Ararat is volcanic. The eruptions in these places seem to be of the greatest antiquity. Volcanic matter about Erzerûm is so widely diffused, that I am disposed to acquit Sestini of exaggeration in his route to Diarbekir." (p. 178.)

about three or four miles from the town of Abullionte, lat. 40°·10. Greenstone rocks however occur still nearer the Sea of Marmora, in lat. 40°·35, behind the town of Moudania.

The other localities are given in a note*, as their enumeration would not much interest the general reader: in two instances they would be referred to the class of modern eruptive rocks according to the definition I have given in this work; in one case a trachytic mass, in another a basaltic, having flowed down the sides of the hill, and resting upon a gravel with rolled pebbles of trachyte.

These however are of great antiquity and imperfect preservation, compared to the rocks in the country east of Smyrna, known of old by the name of Catacecaumene, or Burnt District. The latter is thus described by Strabo†:—

"The Catacecaumene is in length 500 stadia, in breadth 400, whether it be right to call it in Mysia or in Mæonia, for it is considered bothwise. It is without trees, with the exception

* The following are the localities given besides the neighbourhood of the lake of Apollonia:— lat. 40°·10.

1. Hammanli near Kirmasli . . . . . . lat. 39°·56.
2. Eshen, between Harmanjik and Taushauli . lat. 39°·43, long. 29°·20.
3. Valley of the Macestus, several outbursts of trachyte, a coulée of trachyte near Boghaditza.
4. Between Azani and Ghiediz—probably also modern.
5. Gunay, in the midst of hills of secondary limestone . . . . lat. 38°·53.
6. Tahmek, cluster of trachytic cones . . . lat. 38°·26, long. 29°·8.
7. Catacecaumene . . . . lat. 28°·30.
8. About eight miles from Adala, on the road to Koola.

† Μετα δε ταυτ' εστιν ἡ Κατακεκαυμενη λεγομενη χωρα, μηκος μεν και πεντακοσιων σταδιων, πλατος δε τετρακοσιων, ειτε Μυσιαν χρη καλειν, ειτε Μηονιαν· λεγεται γαρ αμφοτερως· ἁπαντα αδενδρος, πλην αμπελου της τον Κατακεκαυμενιτην φερουσης οινον, ουδενος των ελλογιμων αρετῃ λειπομενον. Εστι δε ἡ επιφανεια τεφρωδης των πεδιων· ἡ δ' ορεινη και πετρωδης, μελαινα, ὡς αν εξ επικαυσεως. Εικαζουσι μεν ουν τινες εκ κεραυνοβολιων και πρηστηρων συμβηναι τουτο, και ουκ οκνουσι τα περι τον Τυφωνα ενταυθα μυθολογειν. Ουκ ευλογον δε ὑπο τοιουτων παθων την τοσαυτην χωραν εκπρησθηναι αθροως, αλλα μαλλον ὑπο γηγενους πυρος· εκλιπειν δε νυν τας πηγας· δεικνυνται δε και βοθροι τρεις, οὑς φυσας καλουσιν, ὁσον τετταρακοντα αλληλων διεστωτας σταδιους· ὑπερκεινται δε λοφοι τραχεις, οὑς εικος εκ των αναφυσηθεντων σεσωρευσθαι μυδρων.—Strabo, ed. Falc. p. 900.

of the vine, from which wine is made that yields to none of the most celebrated. The surface of the ground is cindery, and the mountains and rocks are black, as if they had been calcined. Some have supposed the country to have been affected by fire from heaven, and make this the scene of the fables respecting Typhon, but it is not probable that so large a tract should have been burnt by such causes as this, but rather by fire proceeding from the earth. It is true that its sources are now exhausted; but three hollows, called in the country *φυσαι*, still exist, as much as forty stadia apart from one another, which are overhung by rugged rocks, formed in all probability from melted masses of stone, heaved up like bladders."

Now this district was found by Messrs. Hamilton and Strickland to be a tertiary lacustrine basin, surrounded by hills of ancient schistose rocks. It is drained by the Hermus, which escapes at Adala through a narrow gorge in the schistose formation, the closing of which to a sufficient height would again convert the upper country into a lake. Numerous volcanic eruptions have taken place among the older rocks, which formed the southern margin of the basin; and streams of lava, flowing from these foci, have overspread the lacustrine deposits.

The outbursts of volcanic matter are referred by these geologists to three great periods; the first of which would belong to the class of ancient volcanic rocks, according to the definition that has been given of them in this work, having been poured forth before the valleys of the country were excavated; whilst the two latter would both come under the head of modern, as having been ejected subsequently, and consequently having followed the slope of the hills into the valleys at present existing. Nevertheless the volcanic products of the recent period are strikingly distinguished from those of the third by the smoothness of their outline, and by the vegetation that clothes their surface. The cones of several are all flat, rising at an angle of about 20°; their craters have either disappeared, or are marked by only small central depressions, and all their asperities seem to have been smoothed down by time. These are the rocks which chiefly produce he Catacecaumene wine, celebrated now, as in the time of

Strabo. The streams of lava which have flowed from these are level on the surface, and covered with turf. The cones which answer to this description amount to about thirty.

The volcanos of the third or most modern period, on the contrary, are in so perfect a state of preservation, that we might believe them to have been in activity at the present day. The cones rise at an angle of 30° or 32°, and the sand and scoriæ which compose them are so loose as to render the ascent laborious. A few straggling shrubs are the only vegetation which they produce, and the lava which has flowed from them is as rugged and barren as the latest products of Etna or Vesuvius.

The volcanos of this third period are only three in number, and are nearly equal in size, standing almost in a straight line from W. by N. to E. by S., at a distance of about six miles from each other. They are evidently the hills designated by Strabo as φυσαι; and it is to be remarked, that although the most modern in the district, yet no tradition even of their having been in a state of eruption appears to have reached that geographer.

Each of these cones has sent forth streams of lava, which may be traced from the sides, or in one case from the actual margin of the crater, descending into the plain, and interfering with the course of the river Hermus. That from the volcano called Kaplan-Alan has been worn through by the gradual action of the stream to the depth of eighty feet, exhibiting an abrupt escarpment overhanging the present bed of the river, consisting of imperfectly columnar lava. This alone is a sufficient indication of the great antiquity even of the most modern of these eruptions, yet as a sort of scale of the relative antiquity of the coulées belonging to the three periods recognised by Messrs. Hamilton and Strickland, it may be stated, that whilst the valleys have been denuded eighty feet since the volcanos of the third period were in action, the amount of degradation since the second period has been 200 feet, and since the first or oldest, no less than 800 feet. Such at least is the height at which the basaltic rocks, which cap the vast horizontal plateaux of tertiary lacustrine limestone, stand above the level of the existing valley.

Our authors remark on the great similarity between the

volcanos of the Catacecaumene and those of Auvergne, both occurring in continental tracts at a distance from the present sea; both referable to several periods, although on the large scale capable of being classed under two great heads; both rising near the margin of a tertiary lacustrine basin, which they have partially overspread; both having given rise to streams of lava, which have stopped the drainage of the valleys, produced lakes, and been themselves deeply excavated by the action of rivers now flowing; and both, though antecedent to historical records, presenting the sharpness of outline and barrenness of surface incident to the products of volcanos now in action.

I may remark also, that the neighbourhood of these volcanos, like that of Auvergne, is remarkable for its numerous petrifying springs. Quintus Smyrnæus* relates an elegant legend connected with this subject, from which the term *lac lunæ*, applied to that white calcareous incrustation left on the surface of stone by waters of this description, is apparently borrowed; and Strabo relates, that the waters about Hierapolis and Laodicea, now called Eskihissar, possessed the property of dissolving calcareous earth to so remarkable a degree, that when the water was conducted along the vine-

* *'Ηχι ποτ' Ενδυμιωνα παρ' ὑπνωοντα βοεσσιν*
'Υψοθεν αθρησασα κατηλυθε δια Σεληνη
Ουρανοθεν· δριμυς γαρ αγε ποθος ηϊθεοιο
Αθανατην πονεουσαν· ἡς ετι νυνπερ
Ευνης σημα τετυκται ὑπο δρυσιν· αμφι δ' αρ' αυτῃ
Εκκεχυτ' εν ξυλοχοισι βοων γλαγος· οἱ δε νυ φωτες
Θηευντ' εισετι κεινο· το γαρ μαλα τηλοθι φαιης
Εμμεναι εισορoων πολιον γαλα· καὶ δ' ιησι
Λευκον ὑδωρ, και βαιον αποπροθεν ὁπποθ' ικηται
Πηγνυται αμφι ῥεεθρα· πελει δ' αρα λαϊνον ουδας.
Quintus Calaber, x. 127.

"When formerly divine Luna, viewing above from heaven Endymion sleeping by the side of his oxen, came down to him, for a passionate longing for the youth had seized upon the immortal lover. And of her nuptial bed there exists even now a memorial underneath the oaks, for round about this spot the milk of the cows was shed amongst the trees, and mortals behold it with astonishment: for seeing it from afar, you would say that it was white milk, and yet fresh water gushes out from it; and when you have drawn near, it concretes around the very currents, and becomes at length a marble floor."

yards and gardens, the channels became long fences, each a single stone. Yet this strong petrifying property did not prevent them from being potable*.

Dr. Chandler and Mr. Hamilton both remark the extraordinary petrifying properties of the water at the present day, arising no doubt, as of old, from the carbonic acid with which the waters are impregnated, disengaged by volcanic processes from the earth. Neither of these travellers however appear to have discovered the cave called Plutonium, mentioned by ancient writers, near the town of Hierapolis in the same district, which seems to have been another Grotto del Cane, being filled with a noxious vapour speedily fatal to animal life †. The latter was no doubt carbonic acid gas, as in the instance near Naples.

If any traditions have been handed down to us of volcanic eruptions occurring in any part of Asia Minor, they relate probably to the neighbourhood of Mount Taurus in Cilicia.

Homer in the only passage in which he mentions the giant Typhœus, whom after-poets place underneath the volcano of Sicily or of Naples, says, that the resting-place of the monster is reputed to be among the Arimeans, or in the Arimean mountains (*ειν Αριμοις*) ‡. Now the Arimeans were the an-

* *Το δε της απολιθωσεως και επι των εν Λαοδικειᾳ ποταμων φασι συμβαινειν, καιπερ οντων ποτιμων.* Strabo, p. 905.

† It seems that the priests of Cybele claimed a singular exemption from the influence of this vapour; and Dion Cassius, in his account of the cavern, extends it to *all* eunuchs. It is not difficult to understand how this fraud might be maintained, as the specific gravity of the gaseous fluid is such, that it only occupies the bottom of the cavern, so that a bird, or even a quadruped whose head was low, would be immediately suffocated; whilst the priest, walking more upright, might easily proceed as far as the entrance (which is all that Strabo says he saw him do) without feeling the effects—*οἱ δ' αποκοποι Γαλλοι παριασιν απαθεις, ὡστε και μεχρι του στομιου πλησιαζειν, και εγκυπτειν, και καταδυνειν μεχρι ποσου, συνεχοντας ὡς επι το πολυ το πνευμα.* Strabo, p. 903.

I find that Chandler has already made a remark to nearly the same purport. See his 'Travels in Asia Minor,' ch. lxviii. lxix.

‡ *Οἱ δ' αρ' ισαν, ὡσει τε πυρι χθων πασα νεμοιτο.*
Γαια δ' ὑπεστεναχιζε, Διϊ ὡς τερπικεραυνῳ
Χωομενῳ, ὁτε τ' αμφι Τυφωεϊ γαιαν ἱμασσῃ
Ειν Αριμοις, ὁθι φασι Τυφωεος εμμεναι ευνας.—*Iliad*, B. 781.

cient inhabitants of Syria*, and therefore we might infer that this was the country to which Homer alludes †. It is however a curious coincidence, that the Arimeans peopled that part of Mysia near Smyrna in which volcanic appearances are stated by Strabo to exist, and hence that geographer supposes Homer to refer to the latter country, and not to Syria ‡. Thus, after speaking of the country round Philadelphia in Asia Minor (now Allah Shehr near Smyrna), which I shall presently allude to, he adds that it is here the old writers lay the scene of the circumstances related of Typhon, placing there the Arimi and the Catacecaumene, under which names indeed they venture to rank the whole country between Lydia and the Mæander.

But whatever may be thought with respect to the spot referred to by Homer, there can be no doubt that the Greeks were aware of the existence of volcanic phænomena in some part of Cilicia. Thus Pindar, when he speaks of Typhœus

* Syria is called in Scripture, Aram and Padan-Aram (Gen. xxv. 20, and xxviii. 2), from Aram, the fifth son of Shem, from whom the Syrian people were reputed descendants.

† I do not call to my assistance the disputed verse, which is added in some copies to the lines above from Homer, viz.

Χωρῳ ενι δρυοεντι, Ὑδης εν πιονι δημῳ,

as Heyne and the best commentators view it as an interpolation, and are still more opposed to the substitution of the word Ιουδης for Ὑδης, which was originally proposed by Dickinson in his 'Delphi Phœnicissantes,' and afterwards adopted by Wood in his 'Essay on the original Genius of Homer.' As the word Ιουδα does not occur in any classical writer, it is hardly probable that Homer could have employed it.

It has been supposed by Leclerc with somewhat more probability, that the fable of the giant Typhœus, so well described by Hesiod in his 'Theogenia,' vers. 820 to 870, arose from a vague tradition which had reached the Greeks from Phœnicia of the destruction of the cities of the valley of Siddim: he remarks that the lines beginning

Σηληρον δ' εβροντησε και οβριμον

allude to the manner in which the event took place.

‡ Και δη και τα περι τον Τυφωνα παθη ενταυθα μυθευουσι, και τους Αριμους, και την Κατακεκαυμενην ταυτην ειναι φασιν· ουκ οκνωσι δε και τα μεταξυ Μαιανδρου και Λυδων άπανθ' ὑπονοειν τοιαυτα.—*Strabo*, lib. xii.

being crushed under Cumæ and Sicily, says that he was before confined in Cilicia *.

Now Hamilton has lately given a description of Hassan Dagh, a mountain in Cappadocia, 8000 feet above the sea, south-west of Mount Argæus, the highest peak of the Taurus range. Hassan Dagh consists entirely of trachyte and trachytic conglomerates. Several cones, composed of the latter rock or of loose scoriæ, rise near its base, one of which has given off a considerable stream of black vesicular lava, which has flowed into the plain towards the town of Akserai, and is therefore of recent origin. Thus we have exhibited in this locality the same number of periods of volcanic activity as in the Catacecaumene itself; we have the epoch when the trachytic boulders were thrown out and consolidated into a sort of tuff or conglomerate; the epoch when the tertiary marls, sandstones and grits were deposited upon the above conglomerates; that in which the trachyte itself was heaved up bodily through the last-mentioned deposits; that in which the valley between Hassan Dagh and the table-land was excavated; and finally the period when the numerous cones at the foot of the mountain were thrown up, and a stream of lava emitted from one of them.

Rocks of volcanic materials, chiefly tufaceous, extend all the way from Hassan Dagh to the isolated peak of Mount Argæus, the loftiest mountain of the Taurus range, which according to Mr. Hamilton's measurements cannot be less than 13,000 feet above the sea. This also consists of volcanic rocks, its summit being composed of a reddish brecciated and scoriaceous conglomerate, full of fragments of trap and porphyritic trachyte, and constituting nearly the point of junction between two enormous broken craters, one of which

* Ὁς εν αινᾳ Ταρταρῳ κει-
ται θεων πολεμιος
Τυφως ἑκατοντακαρανος, τον ποτε
Κιλικιων θρεψεν πολυω-
νυμον αντρον· νυν γε μαν
ται θ' ὑπερ Κυμας ἁλιερκεες οχθαι,
Σικελια τ' αυτου πιεζει
Στερνα λαχνοεντα.

Pyth. Od. i.

opens to the N.E., the other to the N.W., and the steep sides of which to the north are covered with perpetual snow, for 2000 or 3000 feet below the summit.

As at Mount Etna, numerous cones of pumice and lapilli encircle its base, and traces of streams of black basaltic lava were visible near the foot of the mountain.

Yet gigantic as the scale is in which volcanic agency must have operated at this locality, as well as in the mountain just before mentioned, a still more surprising feature is the occurrence of horizontal tertiary and volcanic rocks over the whole intermediate space, at the height of 4000 feet and upwards above the sea.

"What a mighty effort of elevation," says Mr. Hamilton, "must we not suppose to have been capable of raising a tract of land above 200 miles in length to this great height, without anywhere disturbing the horizontality of the stratification!"

Besides these more conspicuous and extensive foci of igneous eruption, we have evidence, in the works of Fontanier, Hamilton, Ainsworth and others, of the existence of trappean rocks at Angora, Eregli, Sinope, and innumerable other localities in the central and northern parts of Asia Minor.

The geology of the south-western portion of Asia Minor had until lately been neglected, although Riedesel stated that he had discovered lava opposite to Samos; and Dr. Clarke mentions as a report worthy of credit, that in stormy weather a lambent flame has been observed playing upon the face of the precipitous rock overhanging the sea. He does not appear however to countenance the idea, that it is anything more than a phænomenon of the Pietra Mala description.

The neighbouring island of Patmos however would seem, from the account of this same traveller, to be entirely volcanic, consisting of trap rendered porphyritic by large twin crystals of felspar as big as a pullet's egg, which are in the form of a cross, and regarded with superstitious reverence by the ignorant inhabitants *.

Professor E. Forbes, as above mentioned, confirms the volcanic nature of Patmos, and adds, that some of the islands

* Clarke's Travels, vol. vi.

opposite Cnidus are likewise of recent igneous origin. Sulphur is collected in one of them, and there are solfataras now smoking.

Lycia has been lately explored by this last-mentioned naturalist in company with and Lieut. Spratt, but it does not appear that anything of a volcanic nature was discovered by them.

We must not therefore set down as belonging to this class of phænomena, the burning mountain which ancient writers notice as existing in Lycia, the top of which was the resort of lions, the middle of goats, whilst the bottom abounded in serpents, whence arose the fable of the monster Chimæra, the head of which was that of a lion, the middle of a goat, and the hinder parts those of a dragon, and which continually vomited forth flames.

Beaufort, in his 'Caramania,' describes his visit to this mountain, which as of old sent forth fire, not like that of Etna, but quiet and regular. The ancients state that this fire did not even destroy the plants that grew around, and Beaufort remarks the very same thing. "Trees, brushwood, and weeds," he says, "grow close round the crater, never accompanied with noise or earthquakes; nor does it ever eject stones, smoke, or noxious vapours *."

Professor Forbes notices it in the following manner:—

"Not far from the Deliktash on the side of a mountain, is the perpetual fire described by Captain Beaufort.

"The travellers found it as brilliant as ever, and even somewhat increased, for besides the large flame in the corner of the ruins described by Beaufort, there were small jets issuing from crevices in the side of the crater-like cavity five or six feet deep. At the bottom was a shallow pool of sulphureous and turbid water, regarded by the Turks as a sovereign remedy for all skin complaints. The soot deposited from the flames was regarded as efficacious for sore eyelids, and valued as a dye for the eyebrows."

It is evident from these accounts, that the above phænomenon ought not to rank with those of volcanos, but, that like the one of Apollonia in the mountains of Albania, or of the Pietra Mala in the Apennines, it owes its origin to a slow distillation of bituminous matters.

I insert the following extracts from old travellers with the view

* See the 'Description of Caramania,' by Captain Beaufort, R.N. vol. 8vo.

rather of exciting inquiry, than from any great confidence I entertain in the reports which they convey.

Mr. Otter, when at Bylan in 1737, was told of a mountain called Araz Dagiri, about three miles from Scandaroon, from whence fire had for some time issued. Pococke mentions his having heard of this volcano, on his road to Seleucia (now Souvadi), from an English gentleman, but that he had not seen it himself. He also specifies a small hill north of the town of Kepse, between the mouth of the Orontes and the Bay of Scandaroon, from which smoke, and occasionally flames, are seen to proceed. No recent traveller however has confirmed this statement, though Olivier observed at a place not far distant, traces of ancient eruptions.

Russel, in his 'Natural History of Aleppo*,' speaks of a crater-shaped cavity as existing near Scandaroon, which is called by the natives the Sunken Village. Although it has probably no reference to anything of a volcanic nature, as the same author informs us that it is composed of coral, and various sea shells incrusted and consolidated by calcareous matter almost as white as snow, yet I may as well introduce the notice of it given by Pococke in his 'Description of the East†.' According to this traveller, it is a round oval pit, about 100 yards in diameter and 40 in depth, the upper half perpendicular, the lower exceedingly steep. There is only one way down to it, which is passable for beasts. Half-way down there is a grotto worked in the earth, about five feet high and twenty broad.

* Vol. i. p. 57.

† Vol. i. p. 169.

CHAPTER XX.

SYRIA, THE HOLY LAND, AND ARABIA.

Valley of the Jordan volcanic.—The Dead Sea—how formed.—Other volcanic appearances in Syria.—Mount Sinai volcanic.—Zibbel Teir.—Aden—near Mecca, &c.

If we proceed southwards, from the part of Asia Minor we have just been considering, in the direction of Palestine, we shall meet with abundant evidences of igneous action to corroborate the accounts that have been handed down to us by ancient writers, whether sacred or profane, from both which it might be inferred, that volcanos were in activity even so late as to admit of their being included within the limits of authentic history.

From their familiarity with such phænomena, the Prophets seem to have derived some of their most splendid imagery. Thus Nahum, describing the majesty of God, says, that "the mountains quake at him, and the hills melt, and the earth is burned at his presence. . . . . His fury is poured out like fire, and the rocks are thrown down by him." (Nahum, i. 5, 6.)

"Behold," says Micah, "the Lord cometh forth out of his place, and will come down, and tread upon the high places of the earth. And the mountains shall be molten under him, and the valleys shall be cleft, as wax before the fire, and as the waters that are poured down a steep place." (Micah, i. 3, 4.)

"Oh that thou wouldest rend the heavens," says Isaiah, "that thou wouldest come down, that the mountains might flow down at thy presence, as when the melting fire burneth, the fire causeth the waters to boil, to make thy name known to thine adversaries, that the nations may tremble at thy presence! When thou didst terrible things which we looked not for, thou camest down, the mountains flowed down at thy presence." (Isaiah, lxiv. 1—3.)

And Jeremiah, evidently alluding to a volcano, says—"Behold, I am against thee, O destroying mountain, saith the Lord, which destroyest all the earth: and I will stretch out mine hand upon thee, and roll thee down from the rocks, and will make thee a burnt mountain. And they shall not take of thee a stone for a corner, nor a

stone for foundations; but thou shalt be desolate for ever." (Jer. li. 25, 26.)

The destruction of the five cities on the borders of the Lake Asphaltitis, or Dead Sea, can be attributed, I conceive, to nothing else than a volcanic eruption, judging both from the description given by Moses of the manner in which it took place*, and from the present aspect of the country itself.

I presume it is unnecessary to urge, that the reason assigned in Holy Writ for the destruction of the cities alluded to, does not exclude the operation of natural causes in bringing it about, and that there can be no greater impropriety in supposing a volcano to have executed the will of the Deity against the cities of Sodom and Gomorrah, than it would be to imagine, if such an idea were on other grounds admissible, that the sea might have been the instrument in the hands of the same Being for effecting the general destruction of the human race in the case of the deluge.

Whether indeed we choose to suppose the fire which laid waste these places, to have originated from *above* or from *below*, the employment of secondary causes seems equally implied; and if it be urged that the words of Genesis denote that it proceeded from the former quarter, it may, I think, be replied, that a volcanic eruption seen from a distance might be naturally mistaken for a shower of stones, and that we cannot expect from the sacred historian in the case before us, any greater insight into the real nature of such phænomena, than we attribute to him in the analogous instance, in which the sun is said to have stood still at the command of Joshua.

* The following are the words of Scripture:—

Gen. ch. xix.

Vs. 24. Then the Lord rained upon Sodom and Gomorrah brimstone and fire from the Lord out of heaven.

25. And he overthrew those cities, and all the plain, and all the inhabitants of the cities, and that which grew upon the ground.

28. And he (Abraham) looked toward Sodom and Gomorrah, and toward all the land of the plain, and behold, and lo, the smoke of the country went up as the smoke of a furnace.

In Deut. ch. xxix. ver. 23, the neighbourhood of the Dead Sea is described as a country, the land of which is brimstone, and salt, and burning, which is not sown, nor beareth, nor has any grass growing therein.

That the individuals who witnessed the destruction of these places might have been impressed with this notion, will be more readily believed, when we reflect, that in most eruptions the greater part of the mischief occasioned proceeds from the matters ejected, which are often *perceived* only to fall from above; and those who recollect the description given by the younger Pliny of that from Vesuvius, will admit, that a person who had fled from the neighbourhood of that volcano, as Lot is stated to have done from the one near the Dead Sea, at the commencement of the eruption, would probably have formed the same idea of what was taking place; for it appears from the Roman writer, that it was long before he was enabled, even at Misenum, to determine in the midst of the general obscurity, that the cloud of unusual appearance, which was the precursor of the volcanic phænomena, proceeded from the mountain itself.

When Livy mentions the shower of stones, which, according to common report, fell from heaven on Mount Albano*, there can be little doubt, that the phænomenon that gave rise to such an idea was of an analogous description, and we have already seen, that the volcanic action, of which there are such decided evidences in Phrygia, was attributed by some to heavenly meteors: *εικαζουσι τινες*, says Strabo, *εκ κεραυνοβολιων και πρηστηρων συμβηναι τουτο.*

As therefore we have no authority for supposing Moses to have possessed a knowledge of physics beyond that of the age in which he lived, we may venture to apply to his narrative of the destruction of these cities the same remark, which Strabo has made respecting the indications of igneous action presented by the country round Laodicea—*ουκ ευλογον ὑπο τοιουτων παθων την τοιαυτην χωραν εκπρησθηναι αθροως, αλλα μαλλον ὑπο γηγενους πυρος.*

Volney's description of the present state of this country fully coincides with this view†.

The south of Syria (he remarks), that is, the hollow through which the Jordan flows, is a country of volcanos: the bitu-

* See page 170.

† Travels in Egypt and Syria, vol. i. pp. 281, 282. See likewise in the commencement of the novel of the Talisman, a very picturesque and apparently exact description of the neighbourhood of the Dead Sea.

minous and sulphureous sources of the lake Asphaltitis, the lava, the pumice-stones thrown upon its banks, and the hot-baths of Tabaria, demonstrate that this valley has been the seat of a subterraneous fire, which is not yet extinguished. Clouds of smoke are often observed to issue from the lake, and new crevices to be formed upon its banks. If conjectures in such cases were not too liable to error, we might suspect that the whole valley has been formed only by a violent sinking of a country which formerly poured the Jordan into the Mediterranean. It appears certain, at least, that the catastrophe of five cities destroyed by fire must have been occasioned by the eruption of a volcano then burning. Strabo expressly says, "that the tradition of the inhabitants of the country (that is, of the Jews themselves) was, that formerly the valley of the lake was peopled by thirteen flourishing cities, and that they were swallowed up by a volcano." This account seems to be confirmed by the quantities of ruins still found by travellers on the western border.

"The eruptions themselves have ceased long since, but the effects, which usually succeed them, still continue to be felt at intervals in this country. The coast in general is subject to earthquakes, and history notices several which have changed the face of Antioch, Laodicea, Tripoli, Berytus, Tyre, and Sidon. In our time, in the year 1759, there happened one which caused the greatest ravages. It is said to have destroyed, in the valley of Balbec, upwards of twenty thousand persons; a loss which has never been repaired. For three months the shock of it terrified the inhabitants of Lebanon so much as to make them abandon their houses and dwell under tents."

In addition to these remarks of Volney, a recent traveller, Mr. Legh*, states, that on the south-east side of the Dead Sea, on the right of the road that eads to Karrac, red and brown hornstone porphyry, in the latter of which the felspar is much decomposed, syenite, breccia, and a heavy black amygdaloid, containing white specks, apparently of zeolite, are the prevailing rocks. Not far from Shubac, (near the spot marked in D'Anville's map, *Patriarchatus Hierosolymitanus*,) where

* See his account of Syria, attached to Macmichael's Journey from Moscow to Constantinople.

there were formerly copper mines, he observed portions of scoriæ. Near the fortress of Shubac, on the left, are two volcanic craters; on the right, one.

The Roman road on the same side is formed of pieces of lava. Masses of volcanic rock also occur in the valley of Ellasar.

The western side of the valley of the Jordan, according to Rüssegger, is composed of Jura limestone intersected by numerous dykes and streams of basalt, which, with its deep fissures, the earthquakes to which it is subject, and the saline sulphureous springs which have a temperature of 46° cent., attest the volcanic origin of this depression.

The other substances met with in the neighbourhood are no less corroborative of the cause assigned. Thus great quantities of asphaltum appear floating on the surface of the sea, and are driven by the winds to the east and west bank, where they remain fixed. Ancient writers inform us, that the neighbouring inhabitants went out in boats to collect this substance, and that it constituted a considerable branch of commerce. On the south-west bank are hot springs and deep gullies, dangerous to the traveller, were not their position indicated by small pyramidic edifices on the sides. Sulphur and bitumen are also met with on the mountains round.

On the shore of the lake Mr. Maundrell found a kind of bituminous stone, which I infer from his description to be analogous to that of Radusa in Sicily, noticed in my memoir on the geology of that island*:—"It is a black sort of pebble, which being held to the flame of a candle soon burns, and yields a smoke of a most intolerable stench. It has this property, that it loses a part of its weight, but not of its bulk, by burning. The hills bordering on the lake are said to abound with this sort of sulphureous (*qu.* bituminous) stone. I saw pieces of it," adds our author, "at the Convent of St. John in the Wilderness, two feet square. They were carved in basso relievo, polished to as high a lustre as black marble is capable of, and were designed for the ornament of the new church in the convent."

It would appear, that even antecedently to the eruption

* I have since received a specimen of this stone, which turns out to be precisely similar to that of Radusa.

mentioned in Scripture, bitumen-pits abounded in the plain of Siddim. Thus in the account of the battle between the kings of Sodom and Gomorrah and some of the neighbouring princes (Gen. ch. xiv.) it is said, *And the vale of Siddim was full of slime-pits*—which a learned friend assures me ought to be translated *fountains of bitumen.*

Mr. Henderson in his 'Travels in Iceland' will have it, that phænomena similar to those of the Geysers of Iceland existed likewise in this neighbourhood*. The word *Siddim,* he says, is derived from a Hebrew root, signifying "to gush out," which is the identical meaning of the Icelandic word *Geyser,* and it is remarkable that there exists in Iceland a valley called Geysadal, which signifies the "valley of Geysers," and consequently corresponds with the "valley of Siddim."

The latter therefore he thinks should be translated the "valley of the Gushing Mountains."

This author further believes, that Sheddim, the object of the idolatrous worship of the Israelites (Deuter. xxxii. 17, Psalm cvi. 37), translated in our version "Devils," were boiling springs derived from volcanos, and I may add, in corroboration of this opinion, that somewhat similar phænomena at the Lacus Palicorum in Sicily were the objects among the Greeks of a peculiar and equally sanguinary superstition.

He thinks, that it was in imitation of these natural fountains that Solomon caused to be constructed a number of Jetting Fountains, (as he translates the passage,) of which we read in Ecclesiasticus, chap. ii. 6. My ignorance of the Hebrew language precludes me from forming any opinion as to the probability of these conjectures, but the existence of hot springs in the valley, at a much later period than that to which he refers, is fully established.

But besides this volcanic eruption, which brought about the destruction of these cities, it would appear that the very plain itself in which they stood was obliterated, and that a lake was formed in its stead. This is collected, not only from the apparent non-existence of the valley in which these cities were placed, but likewise from the express words of Scripture, where, in speaking of the wars which took place between the

* Vol. i. p. 154.

kings of Sodom and Gomorrah and certain adjoining tribes, it is added, that the latter assembled in the valley of Siddim, which *is* the Salt (*i. e.* the Dead) Sea.

It is therefore supposed that the lake itself occupies the site of this once fertile valley, and that it was produced by the waters of the Jordan, which being without an outlet, would fill the hollow, until the surface, over which they spread themselves, proved sufficiently large, to cause the loss arising from evaporation to be equivalent to the accessions it received from the rains and snows of the mountains in which it took its rise.

This hypothesis assumes, that previously to the existence of the Dead Sea, the Jordan must have had an outlet, either into the Mediterranean or into the Red Sea; and accordingly, when it was discovered by Burckhardt, that there actually existed a longitudinal valley, parallel to the course which the Jordan took before it reached the Dead Sea, as well as to the larger axis of that expanse of waters, running from north to south, and extending from the southern termination of the Dead Sea to the extremity of the Gulf of Akaba*, it was immediately concluded, that this valley was in fact the former bed of the Jordan, which river consequently, prior to the catastrophe by which the Dead Sea was produced, had flowed into this arm of the Red Sea. It was probably through this very valley that the trade between Jerusalem and the Red Sea was in former times carried on. The caravan, loaded at Ezengebe with the treasures of Ophir, might after a march of six or seven days deposit their loads in the warehouses of Solomon. Granting this to be the fact, there then only remained to explain the manner in which the obliteration of this ancient channel might have been effected.

In the former edition of this work I was tempted to suggest, that such a consequence might have resulted, if the volcano which overwhelmed with its ejected materials the cities of the plain, had thrown out at the same time a current of lava sufficiently considerable to stop the course of the Jordan, the waters of which, unable to overcome this barrier, would

* See plate 3, for a Map of Palestine and the Dead Sea, from Burckhardt, in which the relation of that expanse of waters to the Mediterranean and to the Red Sea is clearly shown.

have accumulated in the plain of Siddim until they converted it into the present lake*. I do not know that any traveller has observed what is the ordinary depth of the Dead Sea, but if we only imagine a current of lava, like that which in 1667 proceeded from Etna, and flowed into the sea above Catania, to have descended at right angles to the bed of the river Jordan, the lake need not be supposed very shallow†.

Nor need we be startled at the magnitude of the effect, that we should be obliged to attribute to a cause, comparatively speaking, so insignificant; for if the little rivulet that flows at the foot of the Puy de la Vache in Auvergne was adequate to produce the lake of Aidat, there seems no disproportion in attributing to a river of the size of the Jordan, to say nothing of the other streams, nowise inconsiderable, that must have been affected by the same cause, the formation of a piece of water, which according to the best authorities, is, after all, not more than twenty-four leagues in length by six or seven in breadth.

That the volcanic eruption which destroyed the cities of the Pentapolis was accompanied by the flowing of a stream of lava, may perhaps be inferred from the very words of Scripture. Thus when Eliphaz reminds Job of this catastrophe, he makes use of the following expressions, according to Henderson's translation of the passage:—

Hast thou observed the ancient tract
That was trodden by wicked mortals?
Who were arrested on a sudden,
Whose foundation is a *molten flood.*
Who said to God, Depart from us:
What can Shaddai do to us?
Though he had filled their houses with wealth;
(Far from me be the counsel of the wicked!)
The righteous beheld and rejoiced,
The innocent laughed them to scorn;
Surely their substance was carried away,
And their riches devoured by fire. *Job* xxii. 15—20.

* This must necessarily have been the case, as (according to Maundrell and other travellers) the Dead Sea is inclosed on the east and west with exceeding high mountains.

† A recent traveller, Mr. Carne, speaks of the Dead Sea as so shallow, at least for some distance from its banks, that he was unable to swim in it See his 'Letters from the East.' London, 1826.

The same fact, Mr. Henderson thinks, is implied in the description of the circumstances connected with Lot's escape*.

"Why was he prohibited from lingering in any part of the low land, if not because he would be there exposed to the pestilential volcanic effluvia and to the lava? And what reason can be assigned for his obtaining leave to stop in Zoar, but its lying at some distance from the spot where the lava began to act, as likewise on an elevation whence he could survey the approaching ruin, and retire before the stream reached that place? We accordingly find, that however desirous he was to stay there at first, he quitted it before night, for a still more elevated and safe retreat. '*And Lot went up out of Zoar, and dwelt in the mountain, for he feared to dwell in Zoar.*' (Gen. xix. 30.)

"How natural is the incrustation of his wife on this hypothesis! Remaining in a lower part of the valley, and looking with a wistful eye towards Sodom, she was surrounded, ere she was aware, by the lava, which rising and swelling, at length reached her, and (whilst the volcanic effluvia deprived her of life) incrusted her where she stood, so that being, as it were, embalmed by the salso-bituminous mass, she became a conspicuous beacon and admonitory example to future generations."

An hypothesis very similar to the above, I find suggested by Von Buch in a letter to Dr. Robinson, dated April 20, 1829†; but in spite of this and other authorities in its favour, I am bound to add, that since it originally occurred to me, two facts have come to my knowledge, which render it less plausible than I had at the time conceived.

The first of these is, that the level of the Dead Sea stands considerably below that of the Mediterranean, and consequently of the Red Sea‡; and the second, that the waters of the high western desert, for some distance south of the Dead Sea, find their way northwards into the latter§, instead of flowing in the contrary direction towards the Red Sea, showing

* Henderson's Iceland, vol. i. pp. 153, 154.

† Robinson's Biblical Researches in Palestine, vol. ii. p. 6.

‡ Rüssegger says 1341 feet. Other travellers make it 526—1320—650—and 630 feet. See in particular Wilkie's Life.

§ See Robinson's Biblical Researches in Palestine, vol. ii. p. 602.

that the present level of that part of Arabia is considerably above that of the valley which the Dead Sea occupies.

The watershed between the Dead Sea and the Red Sea Dr. Robinson places at a point as low as the 30th degree of latitude, whereas the most southern point of the Dead Sea is rather above the 30th parallel. M. Bertin fixes the watershed somewhat higher, immediately south of the entrance of Wady Abu Tuhlka into the great longitudinal valley of El Arabah. From this point a ravine or watercourse, called Wady el Jeib, extends to the Dead Sea, within the El Arabah, thus marking still more distinctly that the present slope of the country inclines towards the north.

Now this very circumstance at once affords us an explanation of the existence of a lake or inland sea in the position in which we find it. It must have been the direct consequence of a sinking in the valley which it occupies, and this sinking must have taken place at a time immediately antecedent to that at which the Dead Sea began to be formed; for it seems physically impossible, that the ground not occupied by this wide expanse could have remained dry, as we are told it was, unless there had been at that time an outlet for the waters of the Jordan, or that there could have been an outlet, if its bed had stood at a lower level than the surrounding country. And as the dimensions of this lake are evidently determined by the quantity of water, that flows down from the mountains of Lebanon in which the Jordan derives its birth, I do not see how the Dead Sea could at any former time have been less extensive than it is at present, although Professor Robinson, in his 'Biblical Researches,' gets over the difficulties of the case, by supposing, that prior to the destruction of the cities of the plain, a part of this tract was occupied by a lake, which therefore, according to him, was enlarged only, and not created, by the catastrophe recorded in Scripture.

In short, if the lake was smaller than it is at present, it seems obvious that some outlet must have existed for the waters of the Jordan; and if this be supposed, I see no necessity for assuming any lake at all, which is certainly not warranted by Scriptural authority, whilst the existence of an outlet in a country so depressed below the level of the ocean seems not only unsupported by analogy, but even contrary to the very laws of hydraulics.

We are not however driven in consequence to give up the idea of a volcanic eruption having been the immediate cause of the destruction of these cities, since the sinking of the valley may have been produced by the volcanic action itself: all I would contend for is, that the formation of a lake must have followed very speedily the depression of the land, whatever epoch we choose to assign to the latter catastrophe; and that, in accepting the statement of Scripture with regard to the existence of cities and cultivated regions on the site now occupied by the Dead Sea, we shall find ourselves compelled to return to the old hypothesis of Volney, which, singularly enough, seems more consistent with the Sacred Writings, than are the suggestions of some of those biblical critics who have taken up the subject at a later period.

Briefly then to recapitulate the train of phænomena by which the destruction of the cities might have been brought about, I would suppose, that the river Jordan, prior to that event, continued its course tranquilly through the great longitudinal valley, called El Arabah, into the Gulf of Akabah; that a shower of stones and sand from some neighbouring volcano first overwhelmed these places; and that its eruption was followed by a depression of the whole of the region, from some point apparently intermediate between the lake of Tiberias and the mountains of Lebanon, to the watershed in the parallel of 30°, which occurs in the valley of El Arabah abovementioned. I would thence infer, that the waters of the Jordan, pent up within the valley by a range of mountains to the east and west, and a barrier of elevated table-land to the south, could find no outlet, and consequently by degrees formed a lake in its most depressed portion, which however did not occur at once, and therefore is not recorded by Scripture as a part of the catastrophe *, though reference is made in another passage to its existence *in what was before the valley of Siddim.*

If, as Robinson states, extensive beds of salt occur immediately round its margin, the solution of the contents of these by the waters of the lake would account for their present com-

* See the passage in Ezekiel, chap. xlvii. v. 8, indicating, if it be interpreted literally, the gradual manner in which the Dead Sea was formed, and likewise perhaps the existence of a tradition that its waters once had their exit in the Red Sea.

position, its saltness increasing nearly to the point of saturation owing to the gradual accession of waters from above, which on evaporating would leave their salt behind, whilst the bitumen might either have existed there previously as a consequence of antecedent volcanic eruptions, or have been produced by the very one to which reference is here made.

I do not however see what is gained by attributing the destruction of these cities, as some have preferred to do, to the combustion of these beds of bitumen, as the latter could have been inflamed by no natural agent with which we are acquainted except the volcano itself, which therefore must, *in any case*, be supposed instrumental, and being invoked, will alone enable us to explain all the facts recorded.

It must be at the same time confessed, that much remains to be done before either this or any other explanation can be received as established, and I am disappointed to find, that amongst the crowds of travellers who have resorted to the Holy Land within the last twenty years, so few have paid that attention to the physical structure of the country, which alone could place the subject beyond the limits of doubt and controversy.

The geologist for instance would still find it worth his while to search the rocks which bound the Dead Sea, in order to discover, if possible, whether there be any crater which might have been in a state of eruption at the period alluded to; he should ascertain whether there are any proofs of a sinking of the ground, from the existence of rapids anywhere along the course of the river, and whether south of the lake can be discovered traces of the ancient bed of the Jordan, as well as of a barrier of lava stretching across it, which latter hypothesis Von Buch, I perceive, is still inclined to support; nor should he omit to examine, whether vestiges of these devoted cities can be found, as some have stated, submerged beneath the waters, or buried, like Pompeii, under heaps of the ejected materials.

It appears from Dr. Clarke that there are traces of volcanic rocks between Jerusalem and the sea, especially about the lake of Gennesaret, and Dr. Robinson states, that the volcanic nature of the basin of this lake and of the surrounding country is not to be mistaken. The hot springs, he says, near Tiberias, and at Om Keis, south-east of the lake, as also the

lukewarm fountains along the western shore; the frequent and violent earthquakes that occur; and the black basaltic stones, which thickly strew the ground,—leave no room for doubt on this point. Although the main formation is limestone, yet the basalt continues to appear, more or less, quite through the basin of the Hûleh as far as to Baniâs; the bridge between the lakes, as also the adjacent Khân, are built of basaltic stones; and the wild and dreary region on the east, between that bridge and the lower lake, consists wholly of basalt. Other traces of volcanic action exist to the north-west of Safed, a town utterly destroyed by a tremendous earthquake on January 1, 1837.

The degree of depression of the lake of Tiberias below the Mediterranean would either seem to have been underrated, or that of the Dead Sea estimated as greater than its actual amount*; for as it does not appear that there are any rapids or cataracts between the two lakes, the sinking in the country which has occurred about the Dead Sea must include the borders of the lake of Tiberias, and the whole of the valley of the Jordan be regarded as one great fissure in the limestone range, caused by some volcanic disturbances†.

From this, coupled with Mr. Buckingham's description of the lake of Tiberias‡, which he represents as situated in a

* That of the former being 328, of the latter 1318 feet.—Lieut. Symons.

† Badhia gives a most *poetical* description of the district traversed by him on his road between the Jordan and Damascus :—

" The Phlegrean fields, and all that can present an idea of volcanic destruction, form but a feeble image of the frightful country through which I passed. From the bridge of Jacob to Sassa, the whole ground is composed of nothing but *lava, basalt, and other* volcanic productions : all is black, porous, or carious ; it was like travelling in the infernal regions. Besides these productions, which cover the country, either in detached masses or in loose strata, the surface of the ground is entirely covered with loose *volcanic stones,* from three to four inches in circumference to a foot in diameter, all equally black, porous, or carious, as if they had just come out of the crater. But it is particularly at the approaches to Sassa that the traveller meets with groups of crevices and volcanic mounds, of so frightful a size, that he is seized with horror, which is increased if he allows his imagination to wander to the period when these masses were hurled forth with violence from the bowels of the earth. There are evident signs that all this country was formerly filled with volcanos, for we beheld several small craters in traversing the plain." (Ali Bey's Travels, vol. ii. pp. 261, 262.)

‡ See Buckingham's Travels in Palestine, pp. 448, 468.

deep basin*, surrounded on all sides with lofty hills, excepting only the narrow entrance and outlet of the Jordan at each extreme, we may perhaps be induced to extend to this piece of water the same explanation which I have given with respect to the formation of the Dead Sea.

This too I perceive is the opinion formed on the spot by the traveller Rüssegger, who regards the sea or lake of Tiberias as crateriform, and states that a stream of basaltic lava issues from the mountain of "Salvation" at a height of 955 feet, and flows to the very borders of the lake, in a current no less than a league in breadth at its termination. The lava is partly compact and partly cellular, containing much zeolite.

The stream of the Hieromax also, which flows into the Jordan just where that river issues from the lake of Tiberias, has cut its course through lava; and why may not the same have been the case with the Jordan itself near the same point? May it not therefore be possible that a still more ancient eruption may, by blocking up the course of the Jordan near this spot, have caused the lake itself, and that the water may afterwards have cut itself a passage through the volcanic matter, and thus have regained its old channel?

Nor are these the only traces of volcanos which this country exhibits.

At Sherm, in the peninsula of Mount Sinai, the hills for a distance of two miles presented, says Burckhardt, perpendicular cliffs, formed in half-circles, none more than sixty or eighty feet in height, whilst in other places there was the appearance of volcanic craters. The rock of which these mountains are composed is black, with a slight tinge of red, full of cavities, and with a rough surface; fragments that had been detached from them were seen lying on the road. The cliffs were covered by deep layers of sand, which also overspread the valleys.

Burckhardt thinks it probable that other rocks of the same kind may be found near Ras Abou Mohammed, and that the name of Black Mountains (*μελανα ορη*) applied to them by the Greeks may have arisen from this cause†. It should be

* According to Rüssegger, 955 feet below the level of the Mediterranean.

† Burckhardt's Syria, p. 529.

observed however that low sand-hills intervene between the volcanic rocks and the sea, and that above them towards the higher mountains no traces of lava are found, which circumstance seems to prove that the volcanic matter is confined to this spot. Burckhardt adds, in a letter to the Association*, that the Arabs, as well as the priests of the convent, mention that loud explosions are sometimes heard, accompanied with smoke, proceeding from a mountain called Om Shommar, eight hours S.S.W. of Djebel Mousa, where however he searched in vain for any traces of the kind.

Humboldt observes, that he is satisfied, from the numerous specimens which have fallen under his observation, that the rock from which these volcanos have proceeded is a transition porphyry like that of Mexico.

On the more elevated parts of Mount Sinai no truly volcanic rocks appear to exist, the formation, according to Burckhardt, being chiefly granite, often with hornblende taking the place of mica, a circumstance indeed which led the French Commissioners to propose the substitution of the term "*sinaite*" for *syenite*, for this description of rock, as being characteristic of the rocks of Mount Sinai rather than of those of Syene in Egypt.

On the borders of the Red Sea itself, some indications of volcanic action have been discovered by modern travellers.

The island of Zibbel Teir†, in north latitude 16°, appears from Bruce's statement, which has been confirmed by Rüppell and other recent observers, to contain an active volcano, and rocks possessing the same characters are mentioned as occurring in a group of smaller islets in the same part of the Red Sea, off Loheia‡.

Niebuhr likewise has given some accounts of phænomena allied to those arising from volcanos, and states in particular, that in the valley of Girondel, near Suez, he met with some hot sulphureous springs, on the spot near which, according to vulgar tradition, Pharaoh and his host were swallowed up§.

* Burckhardt's Nubia, Life, &c., p. lxviii.

† The Journal of the Geographical Society (vol. xvi.) also mentions an active volcano in lat. 15° 7′; long. 42°·12, called Saddle Island, one of the Zebayer group, all of which are of igneous origin.

‡ Bruce's Travels, vol. i. pp. 330 and 340.

§ Niebuhr, vol. i. p. 184.

The promontory of Aden*, eighty miles westward of the Straits of Babel-mandel, consists of a bold cluster of volcanic rocks with lofty jagged peaks, and is connected with the main-land by a low isthmus. At the extremity of the promontory next the main-land is an immense, nearly circular crater, in the centre of which upon a flat, little raised above the sea-level, stands the town of Aden. The diameter of the crater is about one and a half mile, and it is surrounded on all sides, except the eastern, with precipices chiefly composed of lava, rising from 1000 to 1776 feet in height. The crater has been rent in two places on the north and south, but is elsewhere entire.

The eastern portion of the crater has undergone a partial subsidence, by which it is brought down to the level of the sea, so that it forms a little bay, containing an island which was originally a part of the crater.

To the northward of this great crater is an immense mass of lofty and jagged volcanic products, probably the remains of smaller craters.

The unfortunate Seetzen†, who is supposed to have been poisoned during his travels over this part of the Arabian peninsula, after noticing the volcanic nature of the mountains about Aden, proceeds to mention the account which he had received of an eruption which took place on the site of the present harbour. The same traveller, for whose competency, as an observer of such phænomena, we have the respectable authority of Von Hoff, ascertained the existence of porous lava at Damar, at about 15° of north latitude, and traced the same in various directions between that place and Mecca.

Similar appearances are exhibited about Medina, which is perhaps not more than 200 miles south of Sherm, where, as we have seen, we have the authority of the accurate Burckhardt for the existence of volcanos.

* Mr. Burr, in the Proceedings of the Geological Society, vol. iii. p. 355.

† Some account of Seetzen's researches may be seen in Baron Zach's Correspondence, in Baron Hanmer's 'Fundgrube des Orients,' and in a small volume entitled 'A Brief Account of the Countries adjoining the Lake Tiberias, the Jordan, and the Dead Sea.' London, 1810.

CHAPTER XXI.

VOLCANIC PHÆNOMENA OF PERSIA AND THE ADJOINING COUNTRIES.

Circassian range—Mount Ararat—Sapan Dagh—Taman—Baku—Demavend.—Earthquakes in Afghanistan.—Volcanic appearances in Cutch—upheaval and submergence of a tract of land in this province.

HAVING stated what volcanic phænomena have been observed in the most western portions of Asia, namely in Asia Minor and in Syria, I will proceed to point out those existing in the next great department of the continent alluded to, including Persia in its widest signification, Mesopotamia, Armenia, and the other countries about the Caucasian chain, Afghanistan, Beloochistan, and in short the whole district bounded by the Caspian on the north, the Euphrates and the Persian Gulf on the south-west, the Indian Ocean on the south, and the Indus on the east. It will be seen that a branch of the Taurus chain, which, as has been already stated, contains traces of modern volcanic action at Hassan Dagh and at Mount Argæus, stretches into Mesopotamia, dividing the valley of the Tigris from that of the Euphrates.

That some part of this is volcanic there seems good reason to suspect. Olivier notices an extinct volcano between Birt and Orfa, two leagues from the latter place, and likewise between Orfa and Mosul, the capital of Curdistan*. He suspects the great mountain Sindsjaar to be volcanic.

It would seem that some indications of the same description existed formerly in the country of Adiabene, between the Tigris and Euphrates, near the city of Nineveh ; for Tzetzes, in his Scholia on Lycophron, v. 704, mentions that the lake of Avernus (λιμνη αορνος), which most persons refer to the neighbourhood of Naples, stood, according to some, near that

* Ker Porter also speaks of what he calls a sulphur desert in Lower Curdistan near Sulimania, and mentions very abundant naphtha springs at Kirkook, a town south of Mosul.

place. In this country there occurred in the year 1822, the earthquake which destroyed the town of Alep, and with it no less than 8000 persons, and which extended its effects over a radius of fifty leagues*.

Kinneir, in his Memoir on the Persian Empire, conjectures that the island of Ormus, at the entrance of the Persian Gulf, may also be volcanic.

Further north the extensive chain of the Caucasus exhibits the most decided evidence of recent igneous processes, as well as of others of a more remote antiquity.

From the lakes of Van and Ourmia on the south, to the 45th parallel on the north, the whole region comprised between the Caspian and the Black Seas bears throughout evidences of volcanic operations.

In my former edition I was able only to bring together detached and vague notices of a few parts of this remarkable region, the difficulties of travelling through which had in general deterred Europeans from exploring any part of the country, excepting that which might lie contiguous to the line of the more frequented routes.

These difficulties however have been at length surmounted by an enterprising Frenchman, M. Dubois de Montpereux, who, aided by the facilities afforded by the Russian government, spent four years in threading the mountains and defiles of this extraordinary region.

To him therefore the glory belongs, of having first presented us with a systematic view of the geology of the Caucasus, as well as of having connected it with that of the Crimea, which also formed the subject of his personal examination.

Sir R. Murchison has already, in one of his addresses to the Geological Society, paid a just tribute to the energy and perseverance of this traveller, as well as to the value of the results he has obtained. I shall therefore proceed without further preface to communicate a brief statement of such parts of his researches as bear any reference to the subject of the present Volume.

It appears then, that at a period, geologically speaking, not very remote, the whole region comprehended between the Euxine and the Caspian was covered with water, which,

* Ferussac, Bulletin des Sciences for May 1825.

as many are led to believe, formed a vast Mediterranean Sea, extending through Central Asia, of which the Lake of Aral, the Caspian, and other large expanses of water now existing, are the remnants.

The first movement by which any part of the Caucasian range was elevated took place at the period of the formation of the Jurassic limestone or oolitic series, and caused an island to be thrown up between the two seas. Subsequently to this event, a deposition took place of schistous and arenaceous beds, which, from such fossils as Gryphites, Hamites, Ammonites, and others, which they contain, seem capable of being identified with the cretaceous and greensand formations.

A great eruption of Melaphyre*, or trap porphyry, then took place, through the instrumentality of which, the chain of Akhaltsikhe, consisting of the above-named secondary deposits, was heaved up above the level of the waters. At this period then there would seem to have existed a great tract of water north of the Caucasian range, covering the space now occupied by those vast Steppes that intervene between the two seas, in the 45th parallel from the Sea of Azof to Astrachan.

South of this sea was the chain of mountains which had been uplifted at the epoch of the chalk formation; then occurred a straight or narrow sea, bounded, on the north by this chain, and on the south by the Caucasian island consisting of Jura limestone, the result of a previous upheaval.

Now it was at this epoch that the volcanic eruptions began, by which the face of the country has been since so much modified.

To the east, bordering upon the Caspian, the melaphyres and porphyritic rocks of Choucha and Kapan were protruded, and in connexion with these are beds of volcanic cinders and of scoriæ mixed with clay, and of a conglomerate in which are Helices, filling up the valley of Bergouchette. The eruption of these volcanic masses has in other parts of the chain formed great circular basins, called by M. Dubois "*amphitheatres*," some of which now remain as lakes, whilst others, previously existing as such, have been, in the course of time, filled up with tertiary deposits, which show the prior date of the volcanic rocks by which they are encircled.

* Melaphyre, according to Brongniart's nomenclature, is a rock, the basis of which is hornblende, the crystals felspar.

North-west of the porphyries of Choucha and Kapan is the volcanic lake of Sevang, 5000 feet above the sea, surrounded by trappean and porphyritic formations. Further still to the north-west is the so-called amphitheatre of Somkhatie, where streams of lava and of obsidian are found, which seem to have their source in the mountain of Trialethi.

South-west of the lake of Sevang is the great volcanic amphitheatre of Central Armenia, separated from that lake by several conical mountains containing craters. Such are Kiotang-dagh, Agmangan, and Naltapa; whilst the Great Ararat (16,254 feet high); the Little Ararat (12,162 feet); Sinak, and Takhaltou to the south; and Alaghez (12,000 feet) to the north-west, complete the circus.

Black or grey lavas, pumice and obsidian, trass or basalt, mixed with trachytes and melaphyres, here form the prevailing rocks. Passing to the north-west of this district, we find, on reaching the river Kour, the volcanic amphitheatre of the High Kour, or of Akhaltsikhé, where augitic lava and beds of scoriæ are alone seen.

As the lakes of Van and of Ourmia have no outlet, it may be conjectured that they have also been produced in the same manner, notwithstanding the great size of each, the lake Van being twenty-two leagues long and fifteen broad; that of Ouzmia twenty-seven long and eight and a half broad. Subsequently then to the formation of these volcanic amphitheatres, tertiary rocks filled the hollows in the midst of them. Of these the lower beds abound in Nummulites, but the upper ones are gypseous and destitute of shells. In addition to this, the basin of Central Armenia contains vast deposits of rock-salt, an additional proof that a salt-lake formerly existed there.

All this succession of geological epochs appears to have preceded the great elevatory movement to which the Caucasian chain owes its existence.

It was then for the first time that Elbrous, Passemta, Kasbek, and the Red Mountains reared their heads above the surrounding country.

The first of these, Elbrous, the most northern of the four, and the one nearest to the Euxine, is a vast crater at once of eruption and of elevation. Trachytic porphyries have here

been pushed through schistose and perhaps granitic rocks, and the secondary beds adjacent, consisting either of Jura limestone or of chalk, are more and more inclined in proportion as they approach this central mass.

Passemta has not been yet explored, but its height is calculated at not short of 14,000 feet.

Kasbek, which stands considerably to the east of Elbrous, was also evidently another focus of volcanic operations. Streams of lava proceeding from it have been traced as far as the village of Kasbek situated at its base.

The Red Mountains lie above the village of Kachaour, on the road from Tiflis to Wladikavkas. Here there is a vast mural precipice, consisting of black slaty rocks nine or ten thousand feet in height, on the summit of which two or three cones of volcanic materials, called from their colour the Red Mountains, are placed. Streams of lava which have proceeded from it fill up a large fissure or valley to a considerable height.

North of Elbrous lies the vast steppe above-mentioned, which is a tertiary formation in perfectly horizontal strata, deposited from the sea that once covered the whole of the country between the Euxine and Caspian. It is dotted over with detached hills, one of which, Bachetau, 4500 feet above the sea, is composed of trachytic porphyry. This volcano however would seem to have been in repose since the tertiary period, as its flanks are covered with undisturbed beds belonging to that class of rocks, but surrounded by a sort of amphitheatre of hills, which consist of cretaceous beds. One of these hills is called Machouka.

None however of the above mountains present any traces of recent eruptions. Mount Ararat indeed has been by one traveller* reported to have emitted flames and smoke within a very late period; and the frequent and destructive earthquakes that occur in its neighbourhood might prepare us for such an event. Morier however, who spent some time at the foot of the mountain, makes no mention of the sort; nor can anything favouring such an idea be extracted from Tournefort, or from later travellers. The following account of the moun-

* Renigg.

tain by Sir Ker Porter will probably convey a tolerably correct notion of its actual structure:—

"On viewing Mount Ararat from the northern side of the plain, its two heads are seen separated by a wide cleft, or rather glen, in the body of the mountain. The rocky side of the greater head runs almost perpendicularly down to the north-east, whilst the lesser head rises from the sloping bosom of the cleft in a perfectly conical shape. Both heads are covered with snow. The form of the greater is similar to the less, only broader and rounder at the top, and shows to the north-west a broken and abrupt front, opening about half-way down into a stupendous chasm, deep, rocky, and peculiarly black. At that part of the mountain the hollow of the chasm receives an interruption from the projections of minor mountains, which start from the sides of Ararat like branches from the root of a tree, and run along in undulating progression till lost in the distant vapours of the plain.

"The dark chasm which I have mentioned as being on the side of the great head of the mountain is supposed by some travellers to have been the exhausted crater of Ararat. Dr. Renigg even affirms it by stating, that in the year 1783, during certain days in the months of January and February, an eruption took place in the mountain, and he suggests the probability of the burning ashes ejected thence at that time reaching to the south side of Caucasus (a distance in a direct line of 220 wersts), and so depositing the volcanic productions which are found there. The reason he gives for this latter supposition is, that the trap seen there did not originate in these mountains, and must consequently have been sent thither by volcanic explosions elsewhere. And that this elsewhere, which he concludes to have been Ararat, may have been that mountain, I do not pretend to deny; but those events must have taken place many centuries ago, even before history took note of the spot, for since that period we have no intimation whatever of any part of Ararat having been seen in a burning state. This part of Asia was well known to the ancient historians, from being the seat of certain wars they describe; and it cannot be supposed, that had so conspicuous a mountain been often or ever (within the knowledge of man) in a state of volcanic eruption, we should not have heard of it from Strabo, Pliny, Ptolemy, or others; but, on the contrary, all these writers are silent on such a subject with regard to Ararat, while every one who wrote in the vicinities of Etna or of Vesuvius had something to say of the thunders and molten fires of those mountains. That there are volcanic remains to a vast extent round Ararat, every one who visits that

neighbourhood must testify; and giving credit to Dr. Renigg's assertion, that an explosion of the mountain had happened in his time, I determined to support so interesting a fact with the evidence of every observation on my part, when I could reach the spot.

"But on arriving at the monastery of Eitch-mai-adzen, where my remarks must chiefly be made, and discoursing with the fathers on the idea of Ararat having been a volcano, I found that a register of the general appearances of the mountain had been regularly kept by their predecessors and themselves for upwards of 800 years; and that nothing of an eruption, or anything tending to such an event, was to be found in any of their notices.

"When I spoke of an explosion of the mountain having taken place in 1783, and which had been made known in Europe by a traveller declaring himself an eye-witness, they were all in surprise; and besides the written documents to the contrary, I was assured by several of the holy brethren who had been resident on the plain for upwards of forty years, that during the whole of that period they had never seen even a smoke from the mountain. Therefore how the author fell into so very erroneous a misstatement, I can form no guess."

The ascent of Mount Ararat was regarded by the natives as impossible, from the steepness of the acclivity, and the constant snows that cover its summit; but it has been accomplished three several times by Professor Parrot of Dorpat, who determined its summit at 16,254 feet above the sea. He confirms the fact that it has no crater, and bears no evidence of any recent eruption, although the great cleft which extends down its north-west side is probably the result of some natural convulsion.

It is composed entirely of volcanic matter, namely of black porphyritic lava with glassy felspar, of black slaggy lava, of pitchstone porphyry, of obsidian, of a dark compact lithoide lava with red streaks, of black pumiceous lava, and of other varieties of igneous rocks.

It would seem then, as its elevation indeed would alone lead us to surmise, to be a subaqueous volcano, but one of extreme antiquity, and retaining no traces of the volcanic movements by which its constituents have been brought together into their present position.

Kinneir also notices a mountain called Sapan Dagh, which, he says, is conical, and has every appearance of being volcanic.

It is situated near the lake of Van, in Armenia, between Erzerum and Betlis. Quantities of obsidian are found along the borders of the lake*.

This mountain has been since explored by Mr. Brant†, who determined its height to be 10,000 feet above the sea, and consequently nearly 5000 feet above the lake of Van; it has a crater on its summit, and is composed of basalt, scoriæ, &c., but is not known to have ever had an eruption.

M. Dubois indulges in some bold speculations, with respect to the consequences that may have resulted from the bursting of some one of those great lakes, which we have seen to lie at so great an elevation above the sea, in the midst of the great mountainous tract of the Caucasus.

Some such event as this he conceives competent for the production of an aqueous inundation, sufficiently wide-spreading to have swept off the face of the earth all the inhabitants of the plain of Mesopotamia, the cradle of the human race, and thus to have brought about such a deluge as the one which the Scriptures record, supposing that catastrophe to have been no more than co-extensive with the limits within which mankind was at the time circumscribed.

Into these speculations I will not venture to follow him, but must point out another system of operations which has been going on for a long time, and which is at present creating very extensive alterations in the relations between the sea and land.

These are the mud-volcanos, as they are called, which continue even at the present time in an active state on either side of the strait through which the waters of the Sea of Azof empty themselves into the Euxine, being met with both in the peninsula of Taman, and on the coast of Asia opposite.

The mud-volcano of Taman is described by Pallas‡ as rising in the midst of a tongue of land rather more than two wersts from the bay which bears that name. It is a small hillock about thirty-eight toises in height, and 300 toises at its base. There was on its summit a cleft, from which proceeded in the year 1794 smoke, and a column of fire fifty feet high and thirty in circumference. Vast

* Kinneir's Travels in Asia Minor, p. 374.

† Geograph. Journ. vol. x. p. 409.

‡ Travels in the Crimea, vol. ii. p. 345.

quantities of mud were thrown up from this aperture with considerable force, and a stream of mud flowed down the hill charged with bitumen. Pallas, when he visited the spot, estimated the quantity of mud on the summit of the mountain at 100,000 cubic feet, and observed several streams of the same extending down the sides of the hillock, the broadest and thickest of which, from its origin to the base of the hill, might measure 400 toises. These streams of mud have in certain cases proceeded some distance along a plain at the foot of the hill, encircling any little rising ground that might lie in their way, so that the latter appear like islands standing out in the midst of a deluge of mud.

The matter thus ejected has a very uniform appearance throughout, having the aspect of an unctuous clay, of a bluish colour, and with little sparkling points of mica disseminated. Crystals of pyrites are found in the midst of it, and a saline efflorescence is seen covering its surface. When wetted it becomes ductile, but when dry it cracks. Fragments of stone are sometimes imbedded, which consist of slate sometimes effervescing from the admixture of lime, of limestone of different kinds, of oxide of iron, and of claystones of various descriptions.

The abyss from which this mass of mud had been vomited was covered with a hardened crust, but a bubbling like that of a closed caldron was audible from below.

Now there is nothing here stated to distinguish the phænomena, except *in degree*, from those of the mud-volcano of Macaluba already described, nor is there any similarity between the *products* evolved and those of a genuine volcano. It is distinctly stated that the mud was not hot, nor do the stones ejected appear to have been subjected to the action of any considerable temperature.

M. de Verneuil, the most recent traveller who has described these mud-volcanos, whilst he impresses us with an idea of their importance as geological agents, says nothing calculated to change our opinion with respect to their nature.

He states that in the peninsula of Taman, and on the eastern side of the Crimea, the country is covered with hills of a conical form more or less regular, which rise to the height of 250 feet, and owe their origin to eruptions of mud. These eruptions are accompanied by subterranean noises, jets of viscous matters carried to a great height, quakings of the ground, evolutions of gas and flame, smoke, and springs of water charged with bitumen.

The position of this system of mud-volcanos at the western extremity of the Caucasus corresponds exactly with that of the similar

phænomena at Baku, met with on the eastern extremity of the chain near the Caspian. Now the operation of these mud-volcanos has in the course of ages brought about great changes in this part of the continent of Asia. It seems probable, as M. Dubois de Montpereux has represented, that at one period the Chersonesus was a cretaceous promontory, separated by a wide expanse of sea from a similar promontory of the Caucasian chain, a few intermediate coral islands alone serving to connect them.

Gradually however, by the operation chiefly of mud-volcanos, so great a number of small islands have been thrown up, that the present strait is nearly blocked up with them, and the configuration of the country accordingly does not accord even with what it was so late as the time of Strabo*. Thus round the island of Taman, which seems itself to owe its origin to mud-eruptions of an early period, are grouped several others, the number of which is gradually increasing owing to the same causes constantly at work.

That some of the islands alluded to have been upheaved within the historic æra, may be inferred, says Sir Roderic Murchison, from the fact, that on the walls of the fortress of Sudal, near Theodosia, in the Crimea, we saw stones procured from coast-cliffs which contained shells of *Cardium edule* and *Mytilus edulis* now living in the adjacent Black Sea, and which we are disposed to think must have been thrown up on the line of the eruption of the mud-volcanos, and parallel to the axis of the Caucasus.

In the year 1814 an island is stated to have made its appearance suddenly in the Sea of Azof, owing probably to the same causes.

The account given states, that on the 10th of May in that year a frightful noise was heard in the sea, round a distance of 200 toises. Flames rose from the water, accompanied by explosions as loud as those of a cannon. A thick smoke was blown about by the violence of the wind, and enormous masses of earth were seen thrown up in the air, together with large stones.

Ten eruptions of this kind took place at intervals of a quarter of an hour. Similar phænomena continued during the night. There then rose out of the sea an island, which threw out from several apertures a muddy substance that acquired by degrees some consistency.

During this time a remarkable smell, which had nothing of a sulphureous nature, was perceived over a space of ten wersts. On the 20th of April a nearer examination of the island was undertaken, and it was found almost inaccessible, being surrounded on all sides with

* See this illustrated in the atlas of maps attached to Dubois de Montpereux's great work.

hardened mud. When they had at last succeeded in reaching the interior of the island, its height above the level of the sea was found to be a toise and a half, and its surface was seen to be everywhere covered with a stony material of a whitish colour*.

Pallas relates a similar event as occurring in the year 1799, in the Sea of Azof opposite to Temrah; and it is probable that the island which Aristotle† notices as having made its appearance off the coast of Pontus, was due to the operation of mud-volcanos.

At Baku‡, a town situated on a small peninsula which stands out on the western side of the Caspian Sea, forming a sort of advanced post of the Russian dominions, phænomena occur of the same description, the rocks consisting chiefly of a bituminous shale, which is in some places so impregnated with petroleum, that wells are sunk for the purpose of obtaining it, from some of which as much as 1000 or 1500 pounds are daily obtained. It is natural that a formation of this kind should give rise to certain pseudo-volcanic phænomena, and I believe that all the facts related by travellers, which have led to the notion of volcanic action existing there, may be referred to this cause.

Hence we may explain the perpetual emission of inflammable gas, which has given to this spot such a sacredness amongst the fire-worshipers of the East, and which consists, not of sulphuretted hydrogen, as is the case in genuine volcanos, but of some form of carburetted hydrogen gas.

Here too, as in the Black Sea, we hear of earthquakes, subterranean thunder, the elevation of great districts of country, and jets of flame rising to a considerable height, but of short duration. When the mud-volcano of Johmah, on the peninsula of Abscheron, east of Baku, was first formed on the 27th of November 1827, flames blazed up to an extraordinary height for a space of three hours, and during the following twenty hours they rose about three feet above the crater, from which mud was ejected. Near the village of Bahlichli, west of Baku, the column of flame rose so high that it could be seen at a distance of twenty-four miles. Enormous fragments of rock, torn doubtless from depths, were hurled to a great distance round§.

---

* Leonhard. Taschenb. der Mineral. x. p. 476.

† Περι Μετεωρων.

‡ See the account of this locality by Prof. Eichwald of Wilna, in Jameson's Journal for April 1833. He says that they ought to be called naphtha-volcanos rather than mud-volcanos, as they always terminate in a large emission of naphtha.

§ Humboldt's Cosmos.

The above facts will be sufficient to show that the subject of mud-volcanos, or *Salses* as they are often called, deserves a place in a work which professes to give a general description of volcanic phænomena. They indicate that the operation of these agents, be it what it may, acts no unimportant part in modifying the relations between the sea and land; and although I have not concealed my own suspicions that their cause may be different from that of genuine volcanos, yet my readers will naturally be swayed by the high authorities who have arrived at an opposite conclusion.

"The opinion," says Sir R. Murchison*, "we formed on the spot, that these mud-volcanos have a deep seat, and are as directly connected with internal igneous agency as any other geological phænomenon of eruption, is, we think, sustained, not only by their extension over a tract 200 wersts in length, that line of direction being coincident with the fires of Baku and other mud-eruptions of the Caspian, but above all by the occurrence of fragments of limestone and shale (unlike any portions of the surrounding strata) which they have ejected with their mud and scoriæ.

"These mud-volcanos are therefore in our estimation the last remnants of ancient and more intense igneous action, by which enormous masses of sedimentary matter have been hurled up in former epochs to constitute the lofty Caucasus."

In the chain of Elburs, which bounds the Caspian Sea on the south, there occurs a lofty mountain called Demavend, which has long been noted as a volcano; and as the Greeks attributed the agitations of Mount Etna to the giant Typhœus burned under it, so the Persians believe that Zohag, one of their sovereigns remarkable for his tyrannies, after being conquered by Feridoun, the ancestor of Zoroaster, was imprisoned in this mountain†.

Feridoun appears to have been a personification of the good, as Zohag was of the evil principle, being confounded with Ahriman; and if we were disposed to follow Buffon in the fanciful picture he has drawn in his 'Epoques de la Nature‡' of the early state of the world, which he supposes to have been at first so subject to the ravages of fire as to be

* Russia.

† Zend-Avesta, translated by Anquetil du Perron, vol. i. part iii. p. 422, and vol. ii. p. 410. Morier, in his Travels in Persia, vol. ii. p. 355, gives rather a different version to the tale. My readers will recollect other particulars respecting Zohag in the novel of the Talisman.

‡ Page 355.

unfit for the maintenance of animal life, we might then imagine the confinement of Zohag within the entrails of the mountain to have been typical of the gradual diminution of the volcanic action, which rendered the country more and more fitted for the habitation of man.

The analogy between the Persian Zohag and the Greek Typhœus holds good in other respects: as Zohag was figured with a serpent growing out of either shoulder, which he was obliged to feed with human blood, so Typhœus is described with a hundred snakes, or a snake with a hundred heads, proceeding from the same part:—

> ....εκ δε οἱ ωμων
> Ην ἑκατον κεφαλαι οφιος, δεινοιο δρακοντος,
> Γλωσσησι δνοφερῃσι λελειχμοτες.—Hesiod, Θ. 824.

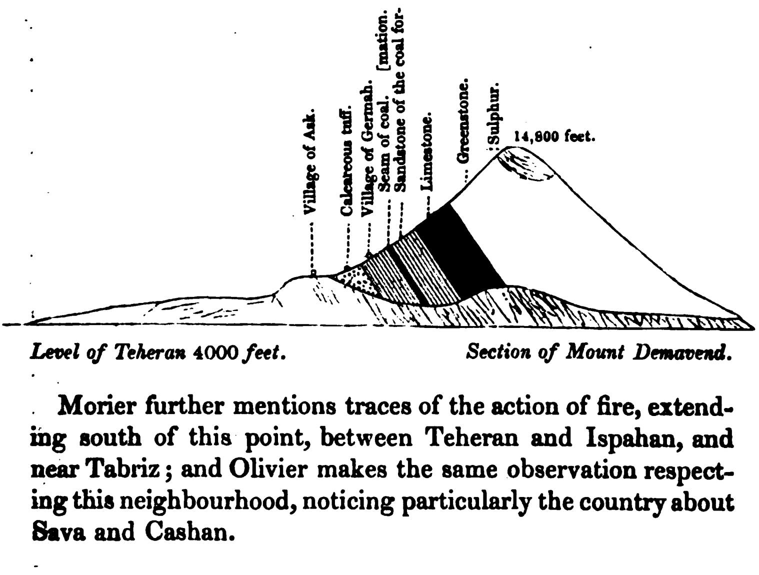
Conformably with this legend, Olivier found on Demavend lava and columnar basalt; Morier states that it is reported sometimes to emit smoke, and that the circumstance of finding sulphur in small craters near the base of the mountain might lead to the conclusion that the cone is itself volcanic. It appears that a considerable commerce in sulphur, as well as saltpetre, is carried on from it.

In September 1837 this mountain was ascended by Mr. Taylor Thomson *, who determined the approximate height by barometrical measurement at 14,800 feet. The last 100 feet from the summit was a mass of pure sulphur, in which was a cave possessing a high temperature from the steam and sulphureous vapour which pervaded it. It is stated, that on the west, below the cone, is a large inclined plain covered with pumice and scoriæ, and having a dark basaltic rock starting up through them to the surface. Mr. Thomson calls it *greenstone* coloured with iron.

This rock however does not continue, at least on the side which Mr. Thomson ascended, far down the flanks of the mountain; it is succeeded by a limestone rock for a thickness of about 1200 feet, underneath which is a sandstone belonging to the coal formation for about 1000 feet, and at the base of the mountain calcareous tufa. Here hot springs of the temperature of 148° of Fahr. occur very abundantly.

* Journ. Geogr. Soc. vol. viii. p. 109.

Upon the whole, it does not distinctly appear to what class of volcanic rocks Demavend must be referred. The structure of the mountain as given by Mr. Thomson is quite an unusual one; the presence of such an accumulation of sulphur on the summit is unexampled, and it is not distinctly stated whether there exists on the top a real volcanic crater, or only a hollow which might be formed either naturally or artificially in a mass of sulphur penetrated by hot vapours.



Level of Teheran 4000 *feet.* *Section of Mount Demavend.*

Morier further mentions traces of the action of fire, extending south of this point, between Teheran and Ispahan, and near Tabriz; and Olivier makes the same observation respecting this neighbourhood, noticing particularly the country about Sava and Cashan.

In those extensive regions that intervene between Persia and the Indus I know of no volcanic mountains of a late date, but earthquakes appear to be frequent and violent.

With one of these, which occurred at Jellalabad during Sir R. Sale's gallant defence of that city, at the time of the disastrous retreat from Cabool, history has made us familiar, and various notices respecting those in the Cabool valley may be collected from the reports of Burnes in the 'Journal of the Asiatic Society,' 'Vigne's Travels,' &c.*

* They have been all brought together in a valuable Memoir by Lieut. Baird Smith, on Indian Earthquakes, Journ. Asiatic Society of Bengal, vol. xii., which contains numerous facts well-worthy of notice relative to this subject.

According to one writer*, "a volcano exists in the Huzzareh mountains to the westward of Cabool. All Afghanistan gives indication of violent volcanic action, and the country from the Kojuck range to beyond the Helmund may be termed a volcanic district, the mountains being usually accompanied along the base by a low range of basaltic or other trap rocks."

In the Valley of Cashmere also earthquakes are common, and according to Mr. Moorcroft, the traditions of the country assert, that the whole of Cashmere, intending thereby the principal line of valley, was originally one large lake; and the aspect of the country confirms the truth of this legend, the subsidence of the waters being distinctly defined by horizontal lines on the face of the mountains. Indications of volcanic action are frequent: hot springs for instance are numerous.

Dr. Falconer states that a singular "field of fire" exists in the valley, of considerable dimensions, and through crevices, in which flames continually issue. The outlines of this volcanic tract are distinctly defined, and the action appears to be strictly local.

It has continued now for upwards of two centuries, as the existence of this remarkable spot is certified by Abul Fazil, the learned minister of the Emperor Akber. Mr. Moorcroft (p. 277) mentions a hill within three days' journey of the city of Cashmere, from which loud explosions are heard at intervals, accompanied by the escape of gaseous matter, with force sufficient to tear off the doors and windows of buildings situated upon it. There was nothing on the hill resembling a crater, but the inhabitants on the spot asserted a distinct recollection of the explosions.

Captain Vickary, in his Report on a portion of the Beloochistan Hills (Quarterly Journal of the Geological Society, No. 7), states that the nummulitic formation which there occurs is broken by many small hills of a conical shape composed of calcined clays of various colours, containing sulphur and scoriæ, and that these seem to have been volcanic vents, emitting gaseous vapours, and perhaps occasionally ejecting stones, but never lava. Tepid springs occur in the same range. In an oral communication made by Dr. Falconer to

* Lieut. Baird Smith.

the Geological Society, it was stated, that in one of the passes through the mountain-chain traversed by our troops in the disastrous retreat from Afghanistan, a river of considerable size is lost underground, but that it seems to come to day again about two miles further, in the form of a copious thermal spring, indicating the existence of volcanic heat underneath.

I shall now proceed to some mention of the volcanic appearances remarked in Hindostan, as having probably some connexion with those we have just been considering, inasmuch as they occur for the most part in its northern and north-western portion, and have not been discovered in any great degree of development in other parts of the peninsula.

I had noticed in my former edition that the island of Salsette near Bombay was basaltic, and that in the elevated table-land of Malwa, which stretches across the country between the parallels of 21·30° and 24° of north latitude, the rocks were principally of trap*. In both instances however there appeared to be nothing in the character or position of the rocks themselves that indicated a recent origin.

Nevertheless Captain Newbold, in his 'Summary of the Geology of Southern India,' states, that the deep and almost semicircular indentation forming the safe and commodious harbour of Bombay, embracing, like the crater-bay of Santorino, many beautiful islets, may have once formed the side of a crater of subsidence. The whole of these islets and the high land by which they are encompassed are chiefly of basalt, and amygdaloid; but no decidedly volcanic products, such as pumice, scoriæ, lapilli, pitchstone, obsidian, &c., have been found.

That some part of this trap formation overspreading Central India has been erupted in the open air, is evident, Capt. Newbold thinks, from the lacustrine deposits it has invaded between Hydrabad and Nagpore, like the Eocene basalts of Auvergne; but the greater part of it must have made its appearance under circumstances of great pressure, and in the bed of the ocean. This may be inferred from the absence of

* Malcolm's Central India, vol. ii. Appendix, on the authority of Captain Dangerfield.

cones and craters of elevation, its usual compact structure, the want of conformity of the trap to the lowest level of the existing valleys, and the occasional intercalation of marine shells.

It appears also from Captain Dangerfield's account*, that some of the hills in the Vindhya range, and in the neighbouring wild tract of Ragpeeplee, have on their summits hollows which resemble crater-lakes. Malcolm† cites the lake of Lonar as a crater, and from the drawing of it given in the 'Asiatic Journal,' there can be little doubt that such is the case.

We have also within a few years obtained from Captain Grant‡ a detailed account of the geology of the province of Cutch, situated between 22° and 24° of north latitude, and therefore parallel with the central table-land above noticed, and about two degrees north of Bombay, from which it would appear, that igneous action has taken place in that quarter in modern times, and that one of the supposed consequences of latent volcanic forces underneath is manifesting itself even at present, in the gradual upraising of a tract of country above the level of the sea, as well as in the submergence of another adjacent district.

The igneous rocks of Cutch are of two kinds, basaltic, and scoriaceous or cellular.

The basaltic appear to have been protruded through the medium of dykes in the midst of secondary and tertiary beds, which both exhibit signs of great disturbance where in contact with the ignigenous rock.

They are also found to alternate repeatedly with strata belonging to the upper secondary formation, which is supposed to correspond to our oolite, and consists of slate-clay, limestone-slate, calcareous grit, and other similar rocks.

In other cases repeated alternations of basalt with travertin occur, showing still more decisively that long intervals of time must have elapsed between the several igneous eruptions.

The basalt is often highly compact and columnar, but sometimes contains nests of zeolite, which where they have fallen

* Malcolm's Central Asia, vol. ii.

† Asiatic Journal, part xvii.

‡ Geol. Trans. second series, vol. v. pt. 2.

out have left vesicular cavities. Rock-crystal and calc-spar is likewise found in the basalt.

The principal mass of igneous rocks lies towards the southern department of the province, and forms a group of hills called the Doura range; but near the shores of the Runn, a great inland estuary which will be afterwards described, occurs an extinct volcano called Denodur Hill. On the summit of this, which is the highest eminence in the country, an irregular crater, it is said, is still visible; but the structure of the mountain, as described by Capt. Grant, does not well accord with this representation, for it appears to be made up in part of loose sandstone and calcareous grit, containing angular fragments of basalt imbedded, whilst a perpendicular wall of basalt continues apparently all round the top, and a stream of the same material runs past its north-western flank and in other places. Small conical hills, composed of horizontal layers of limestone grit or of basalt, are scattered over its sides. I have been particular in describing this mountain, as it is stated in a work of authority* to have been in a state of active eruption in 1819, during the continuance of the tremendous earthquake which the country at that time experienced. That it emitted flames on this occasion may be believed on the testimony of the inhabitants, but this in itself is no proof of the existence of a volcano, as the same has been known to issue during earthquakes from various rocks possessing nothing of an igneous character. Nor were any traces of recent disturbance perceived by Captain Grant when he visited the spot subsequently.

Other isolated hills scattered over this part of the province appear to be similarly constituted, but more evident proofs of recent outbursts are afforded at the village of Wagi-ke-Padda, at a distance of thirty or forty miles from the hill of Denodur, where a high table-land composed of nummulitic marl, flanked by low irregular hills of ironstone and gravel, is moulded into a kind of flat basin, of which the margin is broken into fissures, whilst the interior is interspersed with hillocks and cones of scoriaceous matter like the refuse of a furnace. In the centre of this basin are several circular spaces, like small craters, surrounded by walls of basalt, but more or less broken

* Mr. Lyell's Geology.

away. A talus of volcanic sand covers it at its base. In one of these the basalt is of a columnar character.

These and similar outbursts which appear to have occurred at a recent epoch may account for the remarkable change of level that has taken place in that low tract called the Runn, which has before been alluded to. This district, occupying an area of upwards of 7000 square miles, is dry the greater part of the year, but during the prevalence of the south-west winds it is covered with sea-water, blown up the Gulf of Cutch with which it is in communication, so as to be passable only by camels, and in some seasons with difficulty even by them. Now a tradition exists that the whole of this tract was upheaved about three centuries ago by an earthquake, previously to which there had been depth of water sufficient for ships to ride in the now-called Runn; and this is rendered more credible by what occurred during the earthquake of 1819, when a tract around Sindree, in the immediate neighbourhood of the Runn, for a distance of sixteen miles on each side of the fort, subsided, so as in a few hours to be converted from dry land into sea. At the same time the contrary effect took place within the distance of five miles from Sindree, a long elevated mound being raised where there had been previously a low and level plain, fifty miles in length, sixteen in breadth, and eighteen feet high.

These facts may well prepare us to believe that the whole of the Runn was thus elevated, and this is further corroborated by the discovery of pieces of iron, ship-nails, and even in one instance a boat, buried under alluvium in the midst of this now sandy, half-submerged district.

Captain Grant also points out some singular walls of rock traversing the surface of the Runn, which appear to have been thrown up above the general level, and confirm the idea of an upheaval having taken place.

This earthquake extended to Ahmadhabad, where it proved very destructive, and was sensibly felt at Poonah, a town 400 miles further off. The town of Bhoor, in the immediate vicinity of the Runn, was destroyed.

CHAPTER XXII.

VOLCANOS OF CENTRAL ASIA.

Reports as to volcanos near Khoutché, north of Bokhara—at Mount Tarbagatai—at Mount Tourfan.—Humboldt's opinion.—Erman's doubts as to the existence of real volcanos.—Reports of volcanic phænomena in China.

In Central Tartary we have long had obscure notions as to the existence of volcanos, and M. Ferussac has taken the trouble of collecting, in a number of the 'Bulletin des Sciences*' for 1824, the principal particulars that had been transmitted to us respecting them up to that period.

It would appear from his report, that at the north of Khouei-thsu, and on the southern frontier occupied at the close of the first century of the Christian æra by the Hioungnou Turks, driven westward by the Chinese, there rises a burning mountain called Ho-chan, the Mountain of Fire. On one side of this mountain, add the accounts, all the stones are in a burning and melted state, and flow to a distance of some tens of *li* (i. e. leagues). This melted mass afterwards becomes cold and hard. The inhabitants of the country use for medicine the lava, or more probably the saline particles mixed with it. Sulphur is also met with.

A Chinese writer of the seventh century, in speaking of Khouei-thsu, says:—At 200 *li* (20 leagues) north of this town, there is a white mountain, which is called Aghie. Fire and smoke continually proceed from it; it is from thence that the sal ammoniac comes.

The ancient town of Khouei-thsu is the town of Khoutché of the present time, situated in 41°·37 north latitude, 80°·35 east longitude, according to the observations of the missionaries sent towards the middle of the last century to prepare a map of it. This volcano, which forms a part of the snowy chain of the celestial mountains, (Thian-Chan) must therefore be found nearly in 42°·35 of north latitude. It is probably the same which has at present the name of Khalar. According to the account of the Boukharies, who bring the sal ammoniac to Siberia and Russia, the latter is found south of

* Vol. iii.

Korgos, a town situated on the Ili. So large a quantity of this salt is collected there, that the inhabitants of Khoutché employ it to pay their tribute to China.

The new description of Central Asia, published at Pekin in 1777, contains the following notice:—

"The territory of Khoutché produces copper, saltpetre, sulphur, and sal ammoniac. The latter proceeds from a mountain called the *Mountain of Sal Ammoniac*, which is found on the north of the town. It has many caverns and crevices, which in spring, summer and autumn are filled with fire, so that during the night the mountain seems illuminated by thousands of lamps. No one then can come near it. It is only in winter, during the coldest season, and when the great quantity of snow has stifled the fire, that the people of the country approach; they strip themselves quite naked, in order to collect the sal ammoniac, which is found in the caverns in the form of very hard stalactites; it is for this reason very difficult to detach it.

"Twelve days' journey by the caravan, north of Korgos, is found another town, commonly called Tchougoutchak, in Chinese Mongolia. It is situated at the foot of Mount Tarbagatai, 46°·5 north latitude, and 80°·45 east longitude. Four stations to the east of this town we arrive at the canton of Khoboksar, near Khobok, which falls into the Lake Darlai; there is there a small mountain full of fissures, which are excessively hot, but do not exhale any smoke. In these fissures sal ammoniac sublimes, and attaches itself so strongly to the walls that it is necessary to break the rock in order to collect it."—*Klaproth.*

The Abbé Remusat, in a letter to Cordier*, states his having found in the Japanese edition of the Chinese encyclopædia other particulars respecting this volcano:—

"The sal ammoniac, in Persian 'Nouchadir,' in Chinese 'Naocha,' &c., is drawn from two volcanic mountains of Central Tartary; one is the volcano of Tourfan, lat. 43°·30, long. 87°·11, which has given to the town near it the name of Ho-Tcheou, town of fire; the other is the White Mountain, in the country of Bichbalikh; these two mountains throw out continually flames and smoke. There are cavities there in which they collect a greenish liquid; exposed to the air this liquid is changed into salt, which is the sal ammoniac; the people of the country use it in the preparation of leather. As to the mountain of Tourfan, we observe a column of smoke rise from it perpetually; this smoke is replaced in the evening by a flame like that of a torch; birds and other animals lighted up by it appear of a red colour. The mountain is called the Mount of Fire. In order

* Annales des Mines, 1820.

to search for the salt, they put on wooden shoes, for leather ones would soon be burnt. The people of the country likewise collect the mother waters, which they boil in caldrons, and obtain from thence the sal ammoniac, under the form of loaves, like those of common salt."

Cordier observes, "that the existence of two burning mountains in the midst of the immense table-land bounded by the Ural, the Altai mountains, the frontiers of China, and the Himalaya chain, is a fact well-worthy of attention. Sal ammoniac is never found in Europe in any but a volcanic rock; it is therefore probable, *à priori*, that the origin of it in Asia is that assigned by the Abbé Remusat, and the professed learning of that scholar gives an authority to the facts detailed."

These volcanos are stated to be 400 leagues east of the Caspian Sea, but Ferussac remarks, that as the volcano of Tourfan is situated, according to Père Gaubil, in lat. 43°·30, long. 87°·11, it must lie in the midst of some considerable lakes, and that the volcano of the White Mountain, in lat. 46°, is also between two large lakes, that of Balgasch and Alakougoul.

The Mount of Fire or Ho-chan, now Khoutché, seems to be the same as that twenty leagues north of Khouei-thou, noticed by the Chinese author of the seventh century under the name of Pechan. According to this author the mountain is called Aghie, a word which, according to M. Klaproth, signifies the same as Ho-chan in Chinese. Klaproth thinks that the volcano is situated in 42°·35 north latitude, and is probably the same as Mount Khalar, which, according to the Boukharies, is found south of Korgos, on the river Ili. Thus all this part of Klaproth's statement would seem to relate to one and the same volcano; and the different names of Mountain of Fire and White Mountain, by which it is known, seem to make it correspond with the two volcanos of M. Remusat.

The volcano of the environs of Tchougoutchak must be found at the foot of Mount Chamar, near the Lake Dzaisang, and therefore does not appear to agree with either of those of M. Remusat. The number consequently of the actual volcanos and solfataras in Central Asia seems still involved in much uncertainty.

In the translation made by Hylander, the father*, of a geographical work by Ibn-el-Wardi, mention is made of a mountain in the interior of Asia, from which smoke is seen to arise in the day, and flames by night. This mountain is situated in the country called

* See Bulletin des Sciences for January 1825.

Tim, which Hylander and his son think are the same as the Botom of Edrisi and Abulfeda, and the Bastam of Bakoui.

This country is situated between the Oxus and the Iaxartes. The mountains give rise to the Sogd (the Polytimetus of ancient geographers), a river which waters the Sogdiana. It is worth while to observe also, that, according to the same Arabian writer, this country produces native sal ammoniac, and the substance called Zadj, which is either alum or an aluminous slate. The burning mountain made known to us in this passage must be to the east of the Lake Aral, and of the Caspian Sea.

Pallas also in his 'Travels' mentions a burning mountain, which he visited in the spring of the year 1770, in the government of Oremburg, near the village of Soulpa occupied by the Baschkires, and the river Jourjousen. He speaks of vapours like smoke in the day, and of slight flames at night, but he does not view them as volcanic*.

Other notices might be collected of similar phænomena occurring in parts of this vast tract, but they principally depend upon the authority of the Tartar tribes, and may perhaps turn out to be the same as those already alluded to†.

Such then are the accounts given, on the faith chiefly of Asiatic writers, of the volcanos of Central Asia, which certainly ought not to be rejected as fabulous, solely because they are not communicated to us in the language of science, or may not square with our preconceived opinions.

I perceive also that these reports are countenanced by Baron Humboldt, who in a memoir on Central Asia‡ remarks, that the existence of four volcanos in the valley between the Altai and Himalaya chain, at a distance of 300 or 400 miles from any sea, is unfavourable to the theory which attributes volcanic action to the operation of sea-water upon the unoxidized nucleus of the earth.

This theory will be discussed afterwards, but on the present occasion it may be enough to say, that the existence of true volcanos in the situations mentioned is still doubted by some of those who are most conversant with the structure of the great continent of Asia, as, for example, by the traveller and

* Vol. ii. p. 76.

† See Schlangin, in Pallas, Nordischen Beitragen, vi. p. 111, and do. vii. p. 32; also Falk, Topog. des Russ. Reichs. vol. i. p. 380.

‡ Boué's Journal de Géologie, vol. i., since published in Humboldt's 'Climatologie Asiatique.'

geographer Erman, who in his 'Archiv' for 1843 remarks, "that it becomes every day more probable, that the beds of coal noticed at Irkutsch and at Sabaikal are connected with those of the Altai group, those of Alatou, and many others less known, and that as to the generation of sal ammoniac in the mountains of Bushan and Kokan, which the Russian travellers ascribe to an anomalous kind of volcanic agency, this has been often found to be concomitant on the combustion of beds of coal, as at Dudweiler in the district of Saarbruck in Germany. Perhaps the burning mountain on the river Chatang, which disengages sal ammoniac, will, when further examined, be divested of its volcanic character, and sink into an indication of the extension of that coal formation which crops out in the island of Taman. The geological relations of the surrounding district are not unfavourable to such a conjecture, but we must wait for further information before deciding upon its truth."

I leave the subject therefore still in the same state of uncertainty as it was when I published the former edition of this work, and would only remark, that if the phænomena of Taman, of Baku, and of Demavend are settled to be pseudo-volcanic, the same conclusion may with great probability be extended to the phænomena described as existing in the interior of Tartary.

In China, M. Biot, jun. has collected from records and traditions existing in the country, a list of occurrences bearing more or less reference to the subject of volcanos*:—

780 years B.C. a large tract of land rose suddenly several feet in the district of Ouey.

78 years B.C. a new peak, fifty feet in height, arose on Mount Tay-Chany.

In 125 the mountain You-Toue fell, and destroyed more than 400 people.

In 634, in the northern province of Chensey, a mountain fell and was reduced to fragments.

In 771 an earthquake was experienced for three days in the two districts of Heng and Ting (lat. 40° and 39°), and in many places the earth opened, from which black water gushed out.

* Comptes Rendus, 1840.

In 887, in the district of Ouey, a mountain fell, and the sun was darkened by the dust.

In 1568, at Yo-ting-Hien, the earth opened in many places, and torrents of water and black sand were ejected.

In 1599 A.D. a mountain sunk into the earth, and a lake was formed in its place.

Some of these catastrophes perhaps have no reference to anything of a volcanic nature, but it may be well to take a record of them, in order that, now when the intercourse with this hitherto sealed portion of the globe is gradually increasing, attention may be directed to this class of phænomena.

Klaproth likewise, in Humboldt's 'Central Asia' (Appendix), remarks, that although no active volcanos are known in China, yet that the wells of fire, Ho-tsing, and the mountains of fire, Ho-chan, observed in several parts of the provinces of Yun-nan, Syn-tchhouan, Kouang-u and Chansi, the first two the most western in all China, and therefore very far removed from the sea, may have some connexion with the same cause. The wells of fire however would seem to be brine springs accompanied by an emission of inflammable gas, and although very curious, have no direct reference to the subject of this volume. Of the mountains of fire, one on the border of Thibet is but little known. Another, the most to the south, is in long. 108°·25 east of Paris, and 23°·27 of north lat. Flames are visible from it at night.

Several mountains of fire are found in the province bounded on the north by the great wall. Ammoniacal vapours as well as flames are said to be exhaled from it.

More to the north-east, in east long. 110°·50, north lat. 40°·5, there is a mountain from which proceeds a great heat and a constant noise; a boiling spring adjoins it.

The other notices so evidently refer to the combustion of coal and other pseudo-volcanic phænomena, that I do not think it necessary to detail them.

CHAPTER XXIII.

VOLCANOS OF KAMTSCHATKA AND THE CHINESE SEAS.

Kamtschatka.—Aleutian Islands.—Kurule Islands.—Japan, viz. in Matsmai—Niphon—Kiu-siu.—Islands adjacent—Loo-Choo—Formosa.

Before arriving at any volcanos in Asia in a state of undoubted activity at the present time, we must resort to the north-eastern extremity of that continent, namely to the peninsula of Kamtschatka.

A recent traveller * describes this tract of land "as a confused heap of granite blocks of various heights, thickly piled together, whose pointed, jagged forms bear testimony to the tremendous war of elements amidst which they must have burst from the bowels of the earth."

Nor is the struggle yet ended, as the smoking and burning of volcanos, and frequent shocks of earthquakes sufficiently intimate.

The mountains, with their glaciers and volcanos emitting columns of fire and smoke from amidst fields of ice, afford a picturesque contrast with the beautiful green of the valleys.

A most singular and indescribably splendid effect is produced when the crystal rocks on the western coast are illuminated by the sun, their whole refulgent surface reflecting his rays in every various tint of the most brilliant colours, resembling the diamond mountains of fairy-land, while the neighbouring rocks of quartz shine like masses of solid gold.

Kraskeninikoff, the Russian navigator, in his history of that province, translated into French in 1767, makes mention of three active vents, besides two that only emitted smoke, and two others which appeared extinct.

The active volcanos, according to him, are:—

1. Awachinski †, lat. 53°·17, north of the bay of Awatscha,

* Kotzebue, Voyage round the World.

† For the relative position of these volcanos, see the Map at the end of the volume.

a mountain, the height of which is estimated at 8199 Paris feet. It had an eruption in 1737, followed by a tremendous earthquake, during which the sea overflowed the land, and afterwards receded so far as to leave its bed, between the first and second of the Kurule islands, dry. It is called by Capt. Beechey, Peak Koselskoi.

Ernest Hoffman *, who accompanied Kotzebue's expedition, ascended it; and Postels and Lenz, who were attached to that of Captain Lutkè, made two excursions to it in 1827 and 1828. They found its base composed of transition slates and greywacke, in highly inclined beds, associated with diorites. Their direction is N.W. and S.E.; their dip 50° to the S.W. These rocks extend nearly to the uppermost limit of trees, beyond which trachyte covers the surface in large blocks, until they reached a kind of plain entirely composed of lapilli, into which they sank up to their knees. Rising however from it, at short distances apart, are a great number of little cones, about twelve feet in height and thirty in circumference, each of which gives out sulphuretted hydrogen. From this spot we still further ascend a very precipitous wall of trachyte, which continues to the summit, where there is a crater of vast size continually emitting smoke.

2. Tulbatchinski, which rises to a height of 7410 feet above the sea, situated on a tongue of land between the rivers of Kamtschatka and Tulbatchik. Its first eruption took place in 1739, and caused the country for fifty wersts round to be covered with ashes.

3. Kamtschatka Mountain, otherwise called Klutschew or Kliutshiwsk, the loftiest in the country, being 14,656 Paris feet above the sea, according to the late measurements of Erman, and 15,510 according to Captain Lutkè. It stands in lat. 56°·3, long. 158°·23. It had an eruption in 1737, the same year in which the mountain Awachinski was in activity. It continued for a week to throw out streams of lava with great vehemence. Since that time it usually ejects ashes and scoriæ three or four times a year.

Erman saw this volcano in full activity; a stream of lava,

* I am indebted for these additional particulars to Von Buch's description of the Canary Islands, which have spared me much trouble in consulting the original authorities.

which gave a vivid light during the night, proceeded from a point about 700 feet below the summit, flowing down its north-west side. Judging from the rocks which Erman collected from the mountain, he considered them to differ from those of the other Kamtschatka volcanos, and to consist of dolerite, as being made up of labradorite and augite, the former in large crystals. The currents of lava are very frequent, and the vast masses of ice which they meet often for a time arrest their downward progress, until the dyke being at length broken through by the heat and pressure of the incandescent mass, the whole is precipitated from the summit with a noise audible at a distance of 100 wersts from the spot. Much sulphur is disengaged from the fumaroles and deposited on the snow, which on melting carries it down to the foot of the mountain.

This volcano is connected with another dome-shaped mass 13,000 feet in height, the two together forming a ridge from S.W. to N.E.

To this list, Erman and others have added considerably, enumerating in all no less than thirteen active volcanos in this peninsula.

Of these the two most remarkable not already mentioned are:—

1. The volcano called by English navigators Awachinski or Awatscha, lat. 55°·19, long. 156°·20, which must be distinguished from the one already mentioned, and called by the same name by Kraskeninikoff. It was estimated by Captain Beechey at 10,747 French feet, and is said to be composed of trachyte to its very base.

2. Schewelutsch, lat. 56°·39, long. 159°·9, estimated by Erman at 9904 feet. It has several peaks, but no crater was discernible. The rock of which it is composed, presents a remarkable resemblance to that of the volcanic cones of the Andes, consisting of a mixture of small grains of glassy albite, and of long black and brilliant crystals of hornblende, imbedded in a grey or reddish basis. Abich considers two species of felspar to be present; the one, albite, constituting more than 70 per cent. of the whole; the other, one of the bisilicates, either andesin or oligoclase (see page 13). He regards the rock as a kind of link between andesite and

dolerite, and therefore places it under the head of Trachyte-dolerite.

The valley of Jelowka, which is a prolongation of the great valley of Kamtschatka, is the boundary-line of this volcanic rock. It is here succeeded by clay and talcose slate, with many beds of quartz rock, diorite and serpentine, the whole much inclined. There is therefore a complete separation between this igneous formation and that to which the former volcanos belong.

From Kamtschatka we may, to all appearance, trace a line of volcanic operations along the chain of the Aleutian Islands to the peninsula of Alaschka in North America, where indications of the same kind are said to occur.

Behring's Island is the connecting link, and occurs in the same parallel nearly as Schewelutsch, the most northern of the Kamtschatka range. In the Aleutian group, Von Buch enumerates nine active vents, and on the peninsula of Alaschka, two; the most eastern being on the north coast of Cook's Inlet.

Among the Aleutian group, Langsdorff has described a rock near the island of Unalaschka, 3000 feet in height, consisting of trachyte, which made its appearance in 1796, and seems to have been thrown up all at once from the bottom of the ocean, and not to have been formed by successive accumulations of ejected materials *.

In 1796 it was only two miles and a half in circumference and 350 feet in height; but in 1806, when it was still burning, it had so greatly increased in size, as to require six hours to go round it in a boat, and five to ascend it.

It appears from Otto Von Kotzebue's 'Travels,' that the geological structure of the surrounding rocks is basaltic, though they possess a greater degree of hardness, and resist the action of the weather more completely than basalt usually does. This he attributes to the quartz and augite they contain.

Trachyte and porphyry-slate however appear, from Moritz Von Engelhardt's account, to occur in Unalaschka †.

* See Langsdorff's Voyages, vol. ii.

† See Kotzebue's Voyage, vol. iii. p. 337.

The volcanos of Kamtschatka are connected again on the south with those of Japan by means of the Kurule Islands, where no less than nine active volcanos are said to occur.

This same volcanic band is continued through the islands of Japan, where Von Buch enumerates no less than thirteen active vents.

Of these, three are situated in Jesso, the most northern of the group, near a harbour in the southern portion of the island, to which Broughton in consequence assigned the name of Volcano Bay.

Near the same spot are two detached islands, discovered by Captain Krusenstern, but more particularly described by Dr. Tilesius, who accompanied that navigator in the capacity of naturalist. They are called Oosima and Coosima, and are remarkable for their diminutive size; that of Coosima indeed rising only to the height of 150 fathoms above the water. Both islands appeared to smoke incessantly: and the volcanic appearances at Oosima emanated from a crater, one side of which had fallen in, and was filled with red puzzolana. The hollow between the separated rocks was penetrated with spiracles, which continued in activity under the sea; and the old lava, from which the present cone rises, is seen distinctly near the level of the water.

The island of Jesso is supposed by Krusenstern to have once had a connexion with that of Niphon, where the straits of Matsmai now exist; and the volcanic action going on in all directions around, certainly supplies a sufficient cause for their subsequent disruption.

That Jesso and Niphon were once continuous, may be conjectured from the similar composition of the opposite coasts, the basaltic character of their rocks, and their broken and shattered condition; but of course these grounds are alone liable to great uncertainty, as Krusenstern is quite ready himself to admit.

Now upon the great island of Niphon at least three active vents are noticed as occurring; namely, 1. Peak Tilesius, situated on the western coast, the peak of which is constantly covered with snow.

2. Alemo, north-west of the capital Jeddo, which had a fearful eruption in 1783, destroying seventeen villages and a

vast number of persons, partly from a shower of red-hot stones, and partly from a stream of sulphureous mud which inundated the neighbouring country.

3. Fusi, the loftiest mountain in Japan, south-west of Jeddo. It is constantly emitting smoke, and formerly gave out flames; but these have ceased since a fissure has taken place in one of its sides.

In the island of Kiu-siu, where the Dutch factory of Naugasaki is situated, there are five.

One of these is called Aso, north of Satzuma, which is particularly mentioned by Langsdorff as being the spot where the Christian proselytes, if they refused to renounce their faith, were thrown into the crater of the burning mountain, during the severe persecution carried on against them in the last century.

Of the second, Wunzen near Nangasaki, Siebold* has given us a detailed account. Its height is 1253 metres, and it occupies the centre of the peninsula of Simabara, in the east of the province of Fezen. The first recorded eruption for 1000 years was in 1792, when the top of the mountain began to fall in, and a thick smoke proceeded from it.

Soon afterwards, a fearful earthquake ravaged the whole of the island, destroying the city of Simabara. All at once the southern arm of the mountain was blown into the air with a tremendous explosion, and the fragments falling into the sea, caused the waters to inundate the land. At the same time a great body of boiling water poured down from the crevices of the mountain into the level ground beneath.

The desolation occasioned by the earthquake, and the eruptions of various kinds that occurred from this and several neighbouring volcanic vents, pass all belief. Not a house, except the citadel, built of Cyclopean blocks of stone, escaped destruction. The outline of the coast was completely changed, and it is said 53,000 persons perished.

Earthquakes occur every year in Japan; but the most formidable was that of the 26th of May, 1828, when not only Wunzen and Aso gave signs of commotion, but Metakè, a volcano in the island of Sakurasima, belonging to the pro-

* Siebold, Voyage au Japan, 1838, translated into French.

vince of Satzuma, had violent eruptions. The shocks extended to the island of Niphon, even as far as Jeddo.

There are abundance of hot springs about Wunzen, and in other parts, called by names denoting *little and great Hell.* Into these boiling springs the Christian converts were plunged at the time of the great persecution.

The other two active vents are—Kirisama in the province of Honga, and Tsuruma in that of Bungo.

Several other active volcanos occur in islands belonging to the Japanese group, but the mere enumeration of them would convey but little information; I shall therefore proceed in the next chapter to trace the line of volcanos through the other islands south of Japan.

From the southern point of Japan, a chain of headlands is continued along the group of Loo Choo to Formosa, and thence to the Philippine Islands.

Off Loo Choo* Captain Hall discovered an isolated rock, on which was the crater of a volcano, reduced apparently to the condition of a solfatara. Its sides were stratified, as were also the rocks on the south side of the island, which are penetrated with great dykes of a material more durable than the stone they intersect, and therefore standing out to a considerable distance in relief from the face of the rock.

The island of Formosa is described by Klaproth in Maltbrun's 'Voyages,' and in the 'Asiatic Journal' for December 1824. A high chain of mountains, which is covered with snow in November and December, stretches across the country. Abundance of salt and sulphur is met with, and flames are said to rise occasionally from the waters of the lakes and from the ground. There is a tradition as to the summit of one of these mountains having become the seat of a volcano. There is said to be on the top of the mountain called Pa-lee-fen-shan, a block of iron of the highest antiquity, to which the natives attribute many extraordinary qualities.

M. Stanislaus Julien, in the 'Comptes Rendus' for 1840†, gives, in a letter to Arago, some details respecting two vol-

* See Captain Basil Hall's Voyage to Loo Choo.

† Page 832.

canos in this island. They are both situated on the east, which is peopled by a savage race of men, never subdued by the Chinese, and rarely visited. The accounts are extracted from 'A History of the Pacification of the Island of Formosa,' published in 1723. "During the day," it is said, "columns of smoke are constantly rising, and by night a bright light is visible." In the 'General Geography of China,' published in 1744, we read, under the head of Formosa, of springs, from which inflammable gas escapes, accompanied by an odour of sulphur. There is also in another Chinese work an account of two mountains, known by names indicating *the great and little Mountain of Boiling Water*. The water in the latter is muddy, and bursts forth from the summit of the hill. Several other mountains, from which hot water gushes, and from which flames issue, are noted under the same head.

CHAPTER XXIV.

INDIAN ARCHIPELAGO.

Philippine Islands :—Luçon—north of Luçon—south of Luçon—Fuego—Mindanao—Sangir—Siao—Celebes—Gilolo—Morety—Ternate—Tidore—Motir—Machian—Amboyna—Gounung-Api—Daumer—Timor—Flores—Sumbaya—Java—Sumatra.—Barren Island in the Andaman Group.—Arracan and Chittagong.

I WILL next proceed to point out the volcanos still active in the Indian Archipelago, beginning with the Philippine Islands as the most northern.

Luçon, the largest of this group, contains several.

Near Manilla is that of Taal, described by Chamisso, which had an eruption in 1754, destroying several villages*.

In the interior of the island is the volcano of Aringuay, which had an eruption in 1641. South of Manilla is a peninsula joined to the rest of the island by a narrow neck of land, and called Camarines. In this strip of land, ranged in linear order, are no less than eleven volcanos, first made known to the world by Don Ildefonso de Aragon in his description of the Manilla†. Other of the Philippine Islands are likewise volcanic.

In the island of Mindoro, opposite to Manilla Bay, is the volcano of Ambil, which by the light it emits serves to point out to sailors the passage into the harbour. The little island of Camiguin, north of Luçon, possesses an active volcano which serves also as a landmark.

The volcanic chain is also connected more closely with the island of Formosa by a burning mountain existing in the group of the Babujan Islands intermediate, in which a great eruption that occurred in 1831 drove the inhabitants from the island. The volcanic range is continued south in the islands of Fuego and Mindanao. The volcano of the latter is variously called

* Voy. Pitt. 1820, vii. tab. 5.

† Description Geogr. et Topogr. de la Ysla de Luçon o Nueva Castille: Manilla, 1819. 4to.

Sanguil, Gounong Salatan, Gounong-Api, and the volcano of Mindanao*. Berghaus conceives that at least two volcanos must exist on this island indicated by these several names†.

Between Mindanao and Celebes are two little islands, both volcanic; the most northern of these, Sangir, had an eruption in 1711, which did great damage.

The other, Siao, is said to be, like Stromboli, in a state of constant eruption, but in 1712 the sides of the mountain opened, and cast forth fire‡.

On the north-eastern side of the island of Celebes is a volcano called Kemas, which was heaved up in 1694 after a violent earthquake, which occurred in its greatest force in the neighbouring island of Ternate. It was accompanied with a dreadful eruption, which plunged all the neighbourhood in the most profound obscurity§. All that portion of the island lying between Boelan and Gorontale was destroyed||.

Gilolo, a large island to the east of Celebes, has one active volcano¶ on the western side, which was heaved up in 1673, with a tremendous earthquake, followed by an ejection of much pumice**.

On the north of Gilolo, on the island of Morety, there was formerly a very active volcano.

In the Archipelago of the Moluccas we hear of four: that of Ternate, which was formerly very active, having had eruptions in 1608, 1635, 1653, and 1673, during which it ejected much pumice. Its height is calculated at about 3840 Paris feet.

2. Tidore has also an elevated conical mountain, which appears to be volcanic.

3. Motir has a volcano, which ejected stones in 1778††.

4. Machian, the most southern of the Molucca group, has a volcano, the crater of which is visible from afar. It is stated that in 1646 the mountain was rent from top to bottom,

* Von Buch, Canaries, p. 435.

† Memoir on the Philippines: Gotha, 1832.

‡ Von Buch, p. 434.

§ Phil. Trans. xix. p. 529. or Hutton and Shaw's Abridgement, vol. iv. p. 163.

|| Valentyn, as quoted by Von Buch. ¶ Ibid. ** Ibid.

†† Forrest.

emitted streams of smoke and flames, and was divided into two parts, which now constitute two distinct eminences.

I have noticed a similar phænomenon when speaking of Mount Ararat, though the cause to which the fissure is attributable in that can only be conjectured.

Wawani, in the island of Amboyna, is a very lofty and steep mountain, which had a fearful eruption in the year 1694*, destroying the houses and population at its foot; but although frequent earthquakes have occurred in the island since that time, no eruption had taken place from it till the year 1820, when a new crater opened on its summit†.

Gounung-Api, a mountain in the island of Banda, is an active volcano. It had an eruption in 1694‡, which is described as very awful, and another in 1820, which ejected red-hot stones of prodigious size. There is an engraving of it in Valentyn. A little to the south the island of Sorea is mentioned by a Dutch correspondent of Dr. Lister's to have been convulsed by a volcanic eruption in 1693§. In this case a portion of the mountain sunk down, and a lake appeared in its place filled with incandescent matter. The lake extended itself towards the village of Woroe, and induced the inhabitants to take flight and transport themselves to the island of Banda.

We have hitherto traced the volcanos of the Indian Ocean extending in a straight line from north to south, but here they seem to follow another direction, for whilst a continuation may be traced to the east in New Guinea‖, where Dampier discovered an active volcano in south lat. 5°·33, which sent forth fits of flame at intervals, we may follow the same range to the west in many of the islands that intervene between Banda and that great *focus* of igneous action which exists in Java.

I will enumerate some of these vents, beginning with the island of Daumer, where Valentyn discovered an active volcano.

* Valentyn, ii. p. 104, as quoted by Von Buch.
† Von Buch, Canaries, who quotes Geogr. Ephem. 1824.
‡ Phil. Trans. See Hutton's Abridgement, vol. iv. p. 163.
§ Phil. Trans. 1695.
‖ See map of the volcanic band in the Indian Archipelago.

Between Timor and Ceram is a little island on which Dampier in 1669 saw a volcano burning.

In the island of Timor itself the volcano of the *peak* served, like that of Stromboli, as a sort of lighthouse, seen at more than 300 miles distance. In 1637 this mountain, during a violent eruption, disappeared entirely; a lake at present takes its place.

Captain Bligh, in his 'Voyage to the South Seas,' mentions the existence of a volcano on a high mountain in the island of Flores; it seemed to him to have been in a state of great activity, as the whole island was covered with its products.

But the most considerable, or at least the most formidable in the character of its eruptions, is that of Tomboro in the island of Sumbaya, of which we have a description from the pen of the late Sir Stamford Raffles.

Almost every one, says this writer, is acquainted with the intermitting convulsions of Etna and Vesuvius, as they appear in the descriptions of the poet and the authentic accounts of the naturalist, but the most extraordinary of them can bear no comparison, in point of duration and force, with that of Mount Tomboro in the island of Sumbaya. This eruption extended perceptible evidences of its existence over the whole of the Molucca Islands, over Java, a considerable portion of Celebes, Sumatra, and Borneo, to a circumference of a thousand statute miles from its centre, by tremulous motions and the report of explosions; while within the range of its more immediate activity, embracing a space of 300 miles around it, it produced the most astonishing effects, and excited the most alarming apprehensions. In Java, at the distance of 300 miles, it seemed to be awfully present. The sky was overcast at midday with clouds of ashes; the sun was enveloped in an atmosphere, whose "palpable density" he was unable to penetrate; a shower of ashes covered the houses, the streets, and the fields, to the depth of several inches, and amid this darkness explosions were heard at intervals, like the report of artillery, or the noise of distant thunder.

At Sumbaya itself three distinct columns of flame appeared to burst forth, near the top of the Tomboro mountain, (all of them apparently within the verge of the crater,) and after ascending separately to a very great height, their tops united in the air in a troubled confused manner. In a short time the whole mountain next Sang'ir appeared like a body of liquid fire, extending itself in every direction.

The fire and columns of flame continued to rage with unabated fury, until the darkness, caused by the quantity of falling matter, obscured it at about 8 P.M. Stones at this time fell very thick at Sang'ir, some of them as large as two fists, but generally not larger than walnuts. Between nine and ten P.M. ashes began to fall, and soon after a violent whirlwind* ensued, which blew down nearly every house in the village of Sang'ir, carrying the alaps or roofs, and light parts away with it. In the port of Sang'ir adjoining Sumbaya, its effects were much more violent, tearing up by the roots the largest trees, and carrying them into the air, together with men, horses, cattle, and whatever else came within its influence. [This will account for the immense number of floating trees seen at sea.] The sea rose nearly twelve feet higher than it had ever been known to do before, and completely spoiled the only small spots of rice land in Sang'ir, sweeping away houses and everything within its reach. The whirlwind lasted about an hour. No explosions were heard till the whirlwind had ceased, at about eleven A.M. From midnight till the evening of the 11th, they continued without intermission; after that time their violence moderated, and they were heard only at intervals, but the explosions did not cease entirely till the 15th of July. Of all the villages round Tomboro, Tempo, containing about forty inhabitants, is the only one remaining. In Pekaté no vestige of a house is left: twenty-six of the people, who were at Sumbaya at the time, are the whole of the population who have escaped. From the best inquiries there were certainly not fewer than 12,000 individuals in Tomboro and Pekaté at the time of the eruption, of whom five or six survive. The trees and herbage of every description, along the whole of the north and west of the peninsula, have been completely destroyed, with the exception of a high point of land near the spot where the village of Tomboro stood†. At Sang'ir, it is added, the

* May not the occurrence of whirlwinds as a concomitant of volcanic eruptions account for the fable of the giant Typhœus, who was at once considered the cause of both these effects? See Hesiod Θ. 869, where Typhœus is described as producing those winds which are destructive to man; whereas Notus, Boreas and others, which are useful to him, are of divine origin.

Εκ δε Τυφωεος εσ' ανεμων μενος ὑγρον αεντων
Νοσφι Νοτου, Βορεω τε, και Αργεστεω Ζεφυροιο.
Οἱ γε μεν εκ θεοφιν γενεη, θνητοις μεγ' ονειαρ.
Αἱ δ' αλλαι μαψαυραι επιπνειουσι θαλασσαν.

Ammianus Marcellinus, in describing the earthquake which destroyed Nicomedia, says, that it was accompanied by hurricanes (lib. xvii. c. 7).

† Major Thorn (in his Memoir on the Conquest of Java, 1810, p. 320)

famine occasioned by this event was so extreme, that one of the rajah's own daughters died of starvation.

Tomboro is connected with Java by the little volcanic islands of Lombok and Bali.

Lombok is noticed by Captain Tuckey as having an isolated peak 7500 feet in height.

Bali, severed from Java, according to the traditions of the people by a great earthquake, had an eruption in 1808.

In Java itself the researches of Dr. Horsfield have made known to us one of the most extended tracts of volcanic formations that perhaps anywhere exist. An uninterrupted series of large mountains, varying in elevation from 5000 to 11,000 and even 12,000 feet, and exhibiting by their round or pointed tops their volcanic origin, extends along the axis of the island, very few of them being near the coast-line. The several members of the group, in number thirty-eight, though different from each other in external figure, agree in the general attribute of volcanos, having a broad base gradually verging towards the summit in the form of a cone.

They all rise from a plain but little elevated above the level of the sea, and with very few exceptions, each one must be considered as a separate formation, raised by an exertion of force independent of that which produced the others. Most of these have been built up at a very remote period, and are covered by the vegetation of many ages; but the indications and remains of their former eruptions are numerous and unequivocal. The craters of several are completely extinct; those of others contain small apertures, which continually discharge sulphureous vapours and smoke. Many of them have had eruptions during late years. Almost all the mountains or volcanos in the large series before noticed, are found on examination to have the same general constitution; they are striped vertically by sharp ridges, which, as they approach the foot of the mountain, take a more winding course.

These ridges alternate with valleys, whose sides are of a very various declivity.

speaks of another volcano, on the north coast of Sumbaya, which is considered to be in communication with that of Gounung-Api, three or four miles off.

Large blocks of basalt occasionally project, and in several instances the valleys form the beds of rivers towards the summits of the volcanos; in the rainy season they all convey large volumes of water.

There are also various ridges of smaller mountains, which, though evidently volcanic, may be termed *secondary*, as they appear to have originated from the *primary* volcanos before noticed. They generally extend in long narrow stripes, with but a moderate elevation, and their sides are less regularly composed of the vertical ridges above-mentioned. In most cases a stratified structure and submarine origin may be discovered. They are generally covered with large rocks of basalt; and in some cases they consist of wacke and hornblende, which are found scattered along their base in immense heaps.

Hills of a mixed nature, partly calcareous, partly volcanic, are also met with. The southern coast of the island consists almost entirely of them, rising in many places to the perpendicular height of 80 or 100 feet, and sometimes much higher. These, as they branch inward and approach the central or higher districts, gradually disappear, and either give place to the volcanic series, or alternate with huge masses of basaltic hornblende that appear to assume a regularly stratified structure.

A Dutch writer* has since communicated some further particulars respecting these basaltic rocks. He informs us that almost all the lofty summits of this chain are truncated cones, consisting in general of irregular columns, which present every variety in point of length, thickness, direction, and other circumstances. They are sometimes placed immediately one on the other, sometimes divided by beds of a different material. This arrangement is only exposed in a few places where the streams have laid bare the strata. The action of the elements, assisted perhaps by that of sulphureous vapours, has effected a great destruction of the rock, large masses of which are washed down into the plains after heavy showers. The basalt is of two qualities: 1st, that composing the lower mountains, which is less compact and porphyritic, but contains large concretions of felspar, quartz?, crystallized horn-

* Reinwardt in the Batavian Transactions, published at Batavia in 1823.

blende, and olivine; 2ndly, that constituting the loftier ranges, which is more compact and uniform in structure, and is so impregnated with iron as to attract the magnetic needle, and even to be obedient to its influence.

With regard to the modern lavas of Java, having been favoured with a sight of the specimens brought by Dr. Horsfield himself from the island, and now at the India House, I may remark, that they struck me as being very similar to those of Vesuvius, and that they in several instances appeared to contain much leucite. I observed several specimens of pitchstone, which I was assured constituted dykes.

Reinwardt informs us, that trachyte has only been observed in one spot in the interior of the island, namely the volcano of Tilu; it is a mixture of glassy felspar and black hornblende. As trachyte is rare, it might be expected that pumice and obsidian would be of unfrequent occurrence; they are met with only near the above-named volcano.

Dr. Horsfield has related an effect of volcanic action in this island, which in point of extent seems almost to exceed what has been hitherto noticed in any other part of the globe.

The Papandayang, situated on the south-western part of the island, was formerly one of its largest volcanos, but the greater part of the mountain was swallowed up into the earth in the year 1772, after a short but violent paroxysm. The account which has been transmitted of this event asserts, that near midnight, between the 11th and 12th of August, there was observed about the mountain an uncommonly luminous cloud, by which it appeared to be completely enveloped. The inhabitants, as well about the foot as on the declivities of the mountain, alarmed by the appearance, betook themselves to flight; but before they could all save themselves, the whole mass began to give way, and the greatest part of it actually *fell in* and disappeared in the earth. At the same time a tremendous noise was heard, resembling the discharge of the heaviest cannon. Immense quantities of volcanic substances, which were thrown out at the same time and spread in every direction, propagated the effects of the explosion through the space of many miles.

It is estimated that an extent of ground, belonging to the mountain itself and its immediate environs, fifteen miles long

and six broad, was by this commotion swallowed up in the bowels of the earth. Several persons, sent to examine the condition of the neighbourhood, made report, that they found it impossible to approach the spot, on account of the heat of the substances which encircled it, and which were piled on each other to the height of three feet, although this was on the 24th of September, and thus full six weeks after the catastrophe. It is also mentioned that forty villages, partly swallowed up by the ground, and partly covered by the substances thrown out, were destroyed on this occasion, and that 2957 of the inhabitants perished.

Guntur, or Gounung Guntur, is remarkable as the only volcano in Java known to have given out any streams of lava. Dr. Horsfield traced, from the base of the conical summit to the foot of the mountain, five several eruptions, the latest occurring in 1800. What the reason for this difference may be seems unexplained, as indeed is the general absence of lava-currents from the Javan volcanos, which are not, like the trachytic cones of the Andes, of such an elevation, as to control the force of the streams that struggle to find a vent upwards.

But be the cause of this what it may, the absence of lava-streams imparts a peculiar aspect to the physiognomy of Java.

Mr. Jukes, in a letter with which he has favoured me, remarks, that "the thing which struck him most forcibly was the almost entire absence of anything like hard rock at or near the surface of the ground. Even in the narrow and precipitous ravines furrowing the sides of the mountains, and on the knife-edged crests that separate one ravine from the other, he could see nothing but soft brown loam, apparently volcanic ashes and sand decomposed into clay.

"Even when standing on the great boundary-wall (1000 feet in height on the inside, and 8000 above the sea) which encircles the old crater called the *sandy* sea, a space five miles in diameter, and in which is the present small active vent called the Bromo, there was neither lava nor any other hard stone to be seen, and it was only on looking up to that wall from the inside, that beds of rock could be perceived capped by a thickness of 60 or 100 feet of loose incoherent materials.

"This character, together with the magnificent untouched and almost impervious forests, that mantle over the whole of these mountains with a thick clothing of vegetation, gave to the volcanos of Java

a very different aspect from those of Teneriffe for instance, with their rugged and barren rocks, their sheets of columnar basalt, and black streams of lava.

"It appeared to me that those of Java had long ceased to erupt lava, and have for ages been burying the previous streams under piles of ashes and powder."

With respect to the remarkable eruption already referred to, which took place from Gounung Guntur in the year 1800, Boon Mesch in his 'Dissertatio de Incendiis Montium Javæ,' Lugduni Batav. 1826, has communicated to us, on the authority of Reinwardt, the Dutch traveller in that country, several additional particulars. He states, that a river which descends from this volcanic mountain became at once, swollen in its dimensions, increased in its temperature, and charged with a large quantity of white, acid, sulphureous mud. On the 8th of October the waters came pouring down into the valley, carrying everything before them, sweeping away the carcases of men and sundry animals, and covering the face of the country with a thick coat of mud. The same recurring with even greater violence on the 12th, rocks and trees were carried away, and the whole face of the hitherto fertile valley was altered by the devastating effect of the deluge of mud that had spread over it.

The acid, which was present along with the sulphur, was evidently the sulphuric, derived from the decomposition of sulphuretted hydrogen gas, in the manner that has been before explained *.

It is abundantly produced in Java by the same process, as at Mount Idienne in the most eastern part of Java, described by Leschenault †. This is a volcano, round the crater of which is a great accumulation of sulphur, whilst in its centre is a lake, the waters of which are at times strongly impregnated with sulphuric acid. They discharge themselves into the sea by a river, which issues from the lowest point of the lake, and contains no fish until its acidity has been diminished by the confluence of other streams.

In 1817, during an eruption of the volcano, the waters of

* Page 212. Some further remarks in elucidation of this subject will be offered in a subsequent chapter.

† Annales du Musée, vol. xviii. 1811.

the lake inundated the surrounding country and completely destroyed the vegetation.

It would appear likewise from Dr. Horsfield's description, that Java exhibits phænomena of a similar kind to those noticed in Sicily and at the foot of the Apennines, and there known under the name of "Salses." In the calcareous district (which I suspect to belong to the same class of formations as the blue clay and tertiary limestone of Sicily) occur a number of hot springs, containing in solution a large quantity of calcareous earth, which incrusts the surface of the ground near it. Of these, some are much mixed with petroleum, and others highly saline.

The latter are dispersed through a district of country consisting of limestone, several miles in circumference. They are of considerable number, and force themselves upwards through apertures in the rocks with some violence and ebullition. The waters are strongly impregnated with muriate of soda, and yield upon evaporation very good salt for culinary purposes (not less than 200 tons in the year).

About the centre of this limestone district is found an extraordinary volcanic phænomenon. On approaching the spot from a distance, it is first discovered by a large volume of smoke rising and disappearing at intervals of a few seconds, resembling the vapours arising from a violent surf, whilst a dull noise is heard like that of distant thunder. Having advanced so near that the vision was no longer impeded by the smoke, a large hemispherical mass was observed, consisting of black earth mixed with water, about sixteen feet in diameter, rising to the height of twenty or thirty feet in a perfectly regular manner, and, as it were, pushed up by a force beneath, which suddenly exploded with a dull noise, and scattered about a volume of black mud in every direction. After an interval of two or three, or sometimes four or five seconds, the hemispherical body of mud or earth rose and exploded again.

In the same manner this volcanic ebullition goes on without interruption, throwing up a globular mass of mud, and dispersing it with violence through the neighbouring places. The spot where the ebullition occurs is nearly circular and perfectly level; it is covered only with the earthy particles impregnated with salt water, which are thrown up from below; its circumference may be estimated at about half an English mile. In order to conduct the salt water to the circumference, small passages or gutters are made in the loose muddy earth, which lead it to the borders, where it is collected in holes dug in the ground for the purpose of evaporation.

A strong, pungent, sulphureous smell, somewhat resembling that

of earth-oil (naphtha), is perceived on standing near the site of the explosion, and the mud recently thrown up possesses a degree of heat greater than that of the surrounding atmosphere. During the rainy season these explosions are more violent, the mud is thrown up much higher, and the noise is heard at a greater distance.

This volcanic phænomenon is situated near the centre of the large plain, which interrupts the great series of volcanos, and owes its origin to the same general cause as that of the numerous eruptions met with in this island*.

Amongst the remarkable phænomena connected with volcanic agency which Java affords, is that same abundant evolution of carbonic acid, which has been already described as occurring in the Lago di Ansanto near Naples (page 189). A similar valley in Java has been called the Valley of Death, or Poison Valley (*Guevo Upas*), and by combining the accounts given of it with those respecting the malignant qualities of a particular vegetable production of the island, called the Upas tree (*Antiaris Toxicaria*), that monstrous fable has been concocted, to which Darwin has given currency in those well-known lines of his 'Botanic Garden,' beginning

Fierce in dread silence on the blasted heath
Fell Upas sits, the hydra-tree of death.

Every living thing that enters this fatal valley is arrested there by instant death, and as the same fate awaits any one that may go to the rescue, the ground is covered with the bleached bones of numerous animals, as well as of men, who have from time to time approached the precincts†. Here the bones remain, whilst the soft parts have wasted away, as carbonic acid exerts little action upon the earthy constituents; but in another locality, at Talaga-Bodas, a volcano mentioned by Boon Mesch, on the authority of Reinwardt, where the mephitic vapours are apparently accompanied by sulphuric acid, the bony matter of the animals suffocated by the me-

* Raffles' Java, chap. 10.—See also Breislac, Institut. Geolog. vol. iii. p. 47, for an extract from the Bib. Univ. Juillet 1817, giving an account of the same phænomenon.

† See this spot described in the Geographical Journal, vol. ii., by Mr. Loudon. It is situated near the town of Batur, and appears to be a small crater on the top of a mountain, which, like the Grotto del Cane, can be approached to within a few feet of the bottom.

phitic exhalations is eaten away, whilst the muscles, nails, hair, and skin, remain. The fact at least is vouched for by the Dutch naturalist, the explanation I offer as my own.

A tradition prevails that Java, Sumatra, Bali and Sumbaya were once united, and formed with Hindostan one unbroken tract of land. Even the dates of the separation of these islands are given in the Javanese records. Thus the separation of

	In the Javan year*
Sumatra and Java took place	1114
Bali, Balembangan and Tava	1204
Gilling, Trawangan and Bali	1260
Selo-Parang and Sumbaya	1280

Raffles however justly remarks, that the physical structure of Sumatra is not such as to give countenance to this opinion, as will appear from the following brief account of its volcanos.

In Sumatra then, Marsden has described four volcanos as existing, but the following are all the particulars known concerning them:—

Lava has been seen to flow from a considerable mountain near Priamang, but the only igneous vent this observer† had an opportunity of visiting, opened on the side of a hill about twenty miles inland of Bencoolen, one-fourth way from the top, so far as he could judge. It scarcely ever failed to emit smoke, but the column was only visible for two or three hours in the morning, seldom rising and preserving its form above the upper edge of the hill, which is not of a conical shape, but slopes gradually upwards. He never observed any connexion between the state of the mountain and the occurrence of earthquakes, but it was stated to him, that a few years before his arrival it was remarked during an earthquake to send forth flame, which it does not usually do.

The inhabitants are however alarmed, when these vents all remain tranquil for a considerable time together, as they find by experience that they then become more liable to such convulsions.

* The Javan æra begins seventy-three years later than the Christian.

† Marsden's Sumatra, p. 29.

Dr. Jack, in a short notice of the Geology of Sumatra, (Geol. Trans. vol. i. p. 398, new series,) observes, that the volcanos of this island have somewhat of a different character from those of Java; the former generally terminating at the summit in a ridge or crest, while the latter are more exactly conical, and have for the most part a much broader basis. It appears that the country near Bencoolen before alluded to (between Indrapore and Bencoolen) was visited by order of Raffles in 1818. There is a lake with a cultivated valley to the west, watered by a small river, that descends from a high volcanic mountain called Gounong-Api, which is always smoking. The rocks in this neighbourhood are of trap, either compact or amygdaloidal, sometimes tufaceous; the most remarkable hill is called Gounong Bungko, or Sugar-Loaf Hill; it is composed of irregular masses of trap.

In crossing the island from Bencoolen to Palembang, we traverse a plain, having in the midst of it the mountain called Gounong Dempo, which is the highest in the island, being 12,000 feet above the level of the sea. It is almost always emitting smoke. Hot springs and other volcanic phænomena are common in the neighbourhood. Basalt and trap compose the range of hills between Bencoolen and Cawoor.

The basis of Sumatra is however, in all probability, primitive; granite being found near Menangkabau and at Ayer Bangy. Much limestone derived from coral reefs likewise occurs.

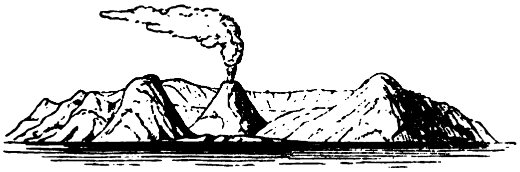
We know nothing of the volcanos said to exist in Borneo, but it appears that the Andaman Islands, west of Pegu and north of Sumatra, contain one in activity, called Barren Island*, nearly 4000 feet in height, which frequently emits vast columns of smoke, and red-hot stones three or four tons in weight.

The relation of this volcano to the circus of rocks which encircles it, except on one point where the sea has made a breach, is regarded by Von Buch as highly illustrative of his elevation-theory, as we seem to have here a cone of eruption thrown up in the midst of a crater of elevation.

* See Colebrooke in the Asiatic Transactions.

Indeed if we compare this locality with Santorino, there will be found nothing but the absence in the latter case of an active vent in the centre of the bay whereby to distinguish it; and from Monte Somma it chiefly differs in its lower level, which causes the bottom of the crater to be sunk beneath the waters of the ocean.

The following sketch will convey an idea of the form and position of this crater,



Section of Barren Island.

This volcanic band appears also to extend to the Burmese peninsula.

The island of Narcaudam, north lat. 13° 22′, Dr. McClelland informs us, is a volcanic cone raised to the height of 700 or 800 feet, and exhibiting traces of lava-currents on its flanks.

The island of Chedooba, lat. 18° 40′, is stated to have an active volcano, though others represent, that the light proceeding from it arises from pseudo-volcanic operations.

The neighbouring island of Rhamree, lat. 19°*, contains mud volcanos similar to those of Chedooba, from which vapour and flame were seen to issue to the height of several hundred feet during the earthquake of August 1833. It is stated† however that an old volcano was re-opened during a tremendous earthquake which ravaged the whole of that peninsula, on the 23rd of March, 1839, stretching in a direction nearly north and south, being felt in the Andaman Islands on the one hand, and extending to China on the other.

On the coast of Chittagong extensive alterations of level, due to volcanic action, are observable. Certain islands ob-

* See also McClelland, Report of Committee for investigating Coal in India, and Lieut. Baird Smith on Indian Earthquakes, in Journ. Asiat. Soc. of Bengal, 1843.

† Silliman's Journal, vol. xxxviii. p. 385.

served in 1554, are now submerged, and a long shoal parallel to the coast alone remains.

The remarkable hot spring about twenty miles to the northward of the town of Chittagong, the gaseous exhalations from which are very considerable, and frequently in a state of ignition, affords probable indications of the same deep-seated cause. In the year 1843 a new island is said to have been formed off the coast of Arracan*.

* Smith on Indian Earthquakes, p. 1055.

CHAPTER XXV.

ISLANDS IN THE PACIFIC OCEAN.

Distinction of the islands in the Pacific into low and high.—LOW islands consist of coral reefs—their several kinds described—theory of their formation—by elevation—by subsidence. HIGH islands volcanic.—Sandwich group—Revillagigedo—Galapagos—Island of Juan Fernandez—Society group—Friendly group—New Hebrides—New Caledonia—New Zealand—Chatham Islands—Van Diemen's Land—New Holland—Mount Erebus.

In the Great Pacific Ocean, the islands, according to Kotzebue*, may be referred to two classes, distinguished by their elevation into *low* and *high*. Those of the former class appear to be entirely of modern formation, the product of that accumulation of coral reefs, which Flinders and others have described in so interesting a manner.

The high islands, on the contrary, are chiefly volcanic, though in the Friendly and Marquesas group primitive rocks occur, and in Waohoo porphyry and amygdaloid.

Now although the latter, being exclusively of aqueous origin, may seem to have nothing to do with the subject of volcanos, yet a little explanation will establish such a connexion between their formation, and the existence of those igneous operations which it is the purpose of this work to elucidate, that it will appear impossible to do justice to the latter, without entering in some degree into the natural history of the coral reefs which are here so abundant.

Mr. Darwin, to whom we are indebted for the most recent, as well as the most philosophical view yet offered on this latter subject, distinguishes coral reefs into three classes, namely Atolls or lagoon islands; barrier reefs; and fringing reefs.

The first of these, Atolls or lagoon islands, are rings of coral reefs surrounding a basin of sea-water of considerable depth, which is inclosed within this area. The reefs are made

* Kotzebue's Voyage of Discovery, vol. ii. p. 355.

up of Porites and Milleporæ, corallines which can only live where they are constantly covered by water. There are also three species of Nulliporæ, which require alternate immersion and emersion, and which fringe the reef for a space of about twenty yards in width.

On this reef many islets are formed, through the accumulation of piles of fragments thrown together from time to time by some unusually strong gale. These become cemented together by the percolation of calcareous matter, and thus resist the further action of the waves.

The lagoon is partially filled up with corallines and with mud proceeding from their detritus. Fish feed on the corals, and excrete their comminuted earthy contents, by which a mass of coralline mud is produced.

The following sketch, from Captain Beechey's 'Voyage,' of Whitsunday Island, in the South Pacific, may serve to represent the aspect of these lagoon islands*:—

Atoll or Lagoon Island.

Barrier reefs differ from Atolls chiefly in containing in their centre an island. The reef is divided from the latter by a body of deep water, just as is the case with the Atolls. Sometimes the reef which encircles the island is entirely converted into land; in others the sea washes over it, excepting in certain places, where portions of the reef project above the level of the waters.

The following sketch, taken from the 'Voyage of the Co-

* Darwin on Coral Reefs. Introduction, page 2.

quille,' will convey an idea of a barrier reef as seen from within*:—

Barrier reef.

Fringing reefs are collections of corallines which skirt the coasts of an island, or part of a continent, in the manner of a barrier reef, from which however they differ in the absence of an interior deep-water channel. It is probable therefore that they grow from that portion of the slope of the continent or island, which, in consequence of its low position, is constantly submerged. These reefs therefore are probably *attached* to the land which they invest, whilst barrier reefs are *detached.*

Atolls are frequent both in the Pacific and Indian Oceans. Thus the Low Archipelago and the Caroline Archipelago in the former, the Maldives and the Laccadives in the latter, are composed of Atolls.

Barrier reefs occur amongst the Society Islands, the Gambier group, and many others in the Pacific. Those in Australia and New Caledonia are remarkable for their great length, in the latter extending 400 miles, and in the former nearly 1000 miles.

Of fringing reefs the Mauritius presents a good example: they extend round the whole island, breached by a straight passage opposite to every river and streamlet. In many places the coast of Brazil is fringed with reefs, which however are not always of coral formation.

Now, as it is on all hands admitted that there is a certain depth below which corallines cannot live, and as the ocean

* Darwin, Coral Reefs, Introduction, page 3.

around many of these reefs is known to be unfathomable, the latter, it is evident, must rest upon some foundation.

Accordingly it has been conjectured that there is under every Atoll or barrier reef, a range of uplifted rock rising nearly to the surface of the water. The limits within which corallines are able to work being from one to about eighty fathoms, the uplifted land must, according to this hypothesis, present a tolerably level surface, not varying more than to that amount. The first question therefore that occurs is, whether such a supposition can be sustained. Doubtless the analogy of mountainous tracts on continents leads to a very different conclusion; but it may perhaps be urged, that the serrated and undulating surface which a mountainous group presents, is caused by the decomposing action of the elements, from which submarine tracts are secured. If we suppose the land underneath the ocean to be upheaved to different heights, some portions rising above the waters, and the rest occupying various levels underneath them, it is evident that corals would only grow upon those portions which were not submerged to a greater depth than eighty fathoms from the surface.

The land above this elevation being exposed at once to the action of the waves and of meteoric agents, might be slowly abraded, until in many cases the whole was ground down below the sea's level, when a thin layer of corallines would immediately be formed upon it. By degrees the whole of that portion of the land which was not *below* the depth at which corals work, would, through their influence, be brought to the surface, and thus an *Atoll or barrier reef* might be formed, according as any portion of uplifted land remained above the waters or not. With regard to the circular or ring-like form of these two kinds of reefs,—this, it has been conjectured, may have arisen from the basis being in each case a volcanic crater; but Chamisso supposes, with greater probability, that as the more massive kinds of coral prefer the surf, the outer portions, in a reef rising from a submarine basis, would first reach the surface, and consequently produce a ring.

Such is the manner in which coral reefs have been explained on the theory of elevation, the most formidable ob-

jection to which is, the necessity of assuming, that in every instance the basis must be supposed to consist of a flat bank; and in the case of a barrier reef there is the further difficulty of supposing, an abrupt sinking round the central island, and then an uprising to a level within eighty fathoms of the surface, and this too continued with the greatest regularity, in some cases for many hundred miles, as is exemplified in the great barrier reef fronting the coast of Australia.

Mr. Darwin has in consequence proposed a theory just the opposite to the foregoing, that namely of subsidence.

He supposes that, at some antecedent period, a large tract of that which now constitutes a part of the Pacific Ocean was dry land; but that it has for many centuries past been slowly subsiding, until at length the upper surface of the rock sunk beneath the level of the waters.

Whenever this event occurred, the coral animals would commence their labours, and would go on building up to the point at which they were no longer covered by the waves and spray.

If therefore this subsidence be supposed to have continued, a provision would exist for the continuation also of this building process, for the land sinking still further, the corals might go on adding to the bulk of the reef, without ever attaining the level of the water; and in this manner during a vast succession of ages, a thickness of coralline matter would be produced, equivalent to the amount of depression which the rock upon which it reposed had in the meantime undergone.

The more vigorous growth of the corals on the outer margin, from having space to expand, and from being freely exposed to the open sea, will account for the annular form which the reef usually assumes, with a hollow within filled with sea-water; and this not only where there is a central island, as in the case of a barrier reef, but also where there is none, as in that of the Atoll or lagoon island.

The absence of this internal hollow between the land and the growing mass of coral serves to show, that in the third kind, the fringing reef, there has been no subsidence; for, had there been any, the progressive rise of the coral on the margin, in a greater ratio than that within, would have by degrees produced a corresponding hollow.

This hypothesis ingeniously explains the great thickness of coral reefs now in the act of forming, in accordance with the habits of the animals which construct them; and it is moreover supported, not only by the proofs of subsidence afforded in other analogous cases by the observations of geologists, who frequently find trees and other productions of dry land standing *in situ*, covered over by several thousand feet of aqueous deposits, but also by the testimony of the inhabitants and casual visitors of these very islands, who speak to the fact of many of them having within a few years undergone a partial submergence.

It is also not improbable, that if an elevation of the crust of the globe is taking place over certain areas, a corresponding sinking of it should occur in others; and Mr. Darwin's own interesting observations in South America (not to mention those of others) have established the fact of a similar upheaval of the continent going on in parts of South America, to that which Linnæus had pointed out as holding good with respect to Scandinavia, where the inquiries of Mr. Lyell have of late fully substantiated its existence.

But whether we adopt the theory of elevation or of subsidence to account for the Coral islands of the Pacific, the agency of volcanic forces seems equally implied, *directly* indeed according to the former view of the case, *indirectly* in the latter, inasmuch as the subsidence of a large tract of the land covered by the Pacific Ocean, may be regarded as the result of a corresponding upheaval of the South American continent by volcanic forces.

This however would imply the absence or paucity of igneous operations over the tract in which Atolls and barrier reefs now abound; but not so in the case of fringing reefs, where, on the contrary, an elevatory movement may be expected to be going on, by which the coral reef will be made to extend itself outwards, in proportion as more and more of the land which had been covered by the waters, is brought within the sphere in which these animalcules can carry on their operations.

It remains then to be seen, whether the situation of the volcanos which exist within the area under our consideration, is such as accords with the above hypothesis.

The Mariana or Ladrone Islands constitute a sort of mountain chain, consisting of a line of active volcanos, especially towards their north, which is parallel to that of the Philippine group, whereas those in the islands that lie detached in the middle of the basin, of which these two groups are the boundaries, seem for the most part to be extinguished*.

Von Buch however states, upon the authority of La Perouse, that there are no less than seven volcanos between these islands and Japan. The Sandwich group is generally stated to contain only one active volcano, namely Kirauea in the island of Owhyhee, of which Mr. Ellis, the missionary, has given us a very vivid description in his 'Tour of Hawaii †.'

The plain, over which their way to the mountain lay, was a vast waste of ancient lava, which he thus describes:—

"The tract of lava resembled in appearance an inland sea, bounded by distant mountains. Once it had certainly been in a fluid state, but appeared as if it had become suddenly petrified, or turned into a glassy stone, while its agitated billows were rolling to and fro. Not only were the large swells and hollows distinctly marked, but in many places the surface of these billows was covered by a smaller ripple, like that observed on the surface of the sea at the springing up of a breeze, or the passing currents of air, which produce what the sailors call a cat's-paw. About two P.M. the crater of Kirauea suddenly burst upon our view. We expected to have seen a mountain with a broad base and rough indented sides, composed of loose slags, or hardened streams of lava, and whose summit would have presented a rugged wall of scoria, forming the rim of a mighty caldron. But, instead of this, we found ourselves on the edge of a steep precipice, with a vast plain before us fifteen or sixteen miles in circumference, and sunk from 200 to 400 feet below its original level. The surface of this plain was uneven, and strewed over with huge stones and volcanic rock, and in the centre of it was the great crater, at the distance of a mile and a half from the place where we were standing. We walked on to the north end of the ridge, where, the precipice being less steep, a descent to the plain below seemed practicable. With all our care, we did not reach the bottom without several falls and slight bruises. After walking some distance over the sunken

* Chamisso in Kotzebue's Voyage of Discovery, vol. ii. p. 353.

† London, 1826, p. 199.

plain, which in several places sounded hollow under our feet, we at length came to the edge of the great crater, where a spectacle sublime, and even appalling, presented itself before us. Immediately before us yawned an immense gulf, in the form of a crescent, about two miles in length from north-east to south-west, nearly a mile in width, and apparently 800 feet deep. The bottom was covered with lava, and the south-west and northern parts of it were one vast flood of burning matter, in a state of terrific ebullition, rolling to and fro its 'fiery surge' and flaming billows. Fifty-one conical islands of varied form and size, containing so many craters, rose either round the edge, or from the surface of the burning lake; twenty-two constantly emitted columns of grey smoke, or pyramids of brilliant flame; and several of these at the same time vomited from their ignited mouths streams of lava, which rolled in blazing torrents down their black indented sides, into the boiling mass below. The existence of these conical craters led us to conclude that the boiling caldron of lava before us did not form the focus of the volcano; that this mass of melted lava was comparatively shallow; and that the basin in which it was contained was separated by a stratum of solid matter from the great volcanic abyss, which constantly poured out its melted contents through these numerous craters into this upper reservoir. The sides of the gulf before us, although composed of different strata of ancient lava, were perpendicular for about 400 feet, and rose from a wide horizontal ledge of solid black lava of irregular breadth; but extending completely round, beneath this ledge, the sides sloped gradually towards the burning lake, which was, as nearly as we could judge, 300 or 400 feet lower. It was evident that the large crater had been recently filled with liquid lava up to this black ledge, and had, by some subterraneous canal, emptied itself into the sea or under the low land on the shore. The grey, and in some places apparently calcined sides of the great crater before us—the fissures which intersected the surface of the plain on which we were standing—the long banks of sulphur on the opposite side of the abyss—the vigorous action of the numerous small craters on its borders—the dense columns of vapour and smoke that rose at the north and south end of the plain—together with the ridge of steep rocks by which it was surrounded, rising probably in some places 300 or 400 feet in perpendicular height, presented an immense volcanic panorama, the effect of which was greatly augmented by the constant roaring of the vast furnaces below*."

* Mr. Ellis's work, though not scientific, will prove of interest to the naturalist from the notices of volcanic phænomena with which it is inter-

This volcano had an eruption in 1832, which was witnessed by the unfortunate Douglas*. He also describes the lava as in ebullition, and in a state of such liquidity as to flow down the mountain at the rate of three miles and a quarter an hour. He describes two lakes of liquid lava existing within the crater, also in a state of furious ebullition, sometimes spouting up

---

spersed, and deserves on that account to be placed by the side of Henderson's Iceland, to which I have had occasion to refer.

His account is enlivened by introducing a few of the legends to which the striking natural phænomena of the island have given rise ; for the natives of Owhyhee, like the Greeks and Persians of old, have peopled the recesses of the mountain Kirauea with a tribe of deities, both male and female, the belief in whose power, kept alive as it is by repeated volcanic explosions, was too deeply rooted in their minds to be effaced even by the authority of their sovereign, who in 1819 decreed the summary abolition of all idolatrous worship.

The natives still persist in believing that the conical craters of the mountains are the houses of their gods, where they frequently amuse themselves by playing at konané (a game like draughts) ; that the roaring of the furnaces and the crackling of the flames are the music of their dance ; and that the red flaming surge is the surf in which they play, sportively swimming on the rolling wave.

Some of their legends may remind us of those that prevailed among the Greeks.

Thus one of their kings, who had offended Pèlè, the principal goddess of the volcano, is pursued by her to the shore, where leaping into a canoe he paddles out to sea. Pèlè, perceiving his escape, hurls after him huge stones and fragments of rocks, which fall thickly around, but do not strike the canoe. A number of rocks in the sea are shown by the natives, which, like the Cyclopean Islands at the foot of Mount Etna, are said to have been those thrown by Pèlè to sink the boat.

I recommend the perusal of this legend (which may be seen in page 266 of Mr. Ellis's book) as very characteristic of the manners and feelings of savage life. The king is represented as taking little pains to secure the escape of any one but himself, for his mother, wife and children are all abandoned without compunction ; his conduct to the friend who accompanies him is the only trait which redeems his character from the charge of utter selfishness ; nor among the natives who tell the story, is their praise of the adroitness with which he effected his escape, at all less commended on account of this desertion of his nearest relations.

* See Journ. of the Geographical Society, vol. iv. This active naturalist met with a horrible death, as is well known, by falling into a pit made by the natives of the Sandwich Islands for catching wild bulls, one of the latter being in it at the time.

to the height of from twenty to seventy feet, rolling and tumbling in fiery waves, and finally precipitated down a ledge of rock to a depth of about forty-three feet, with a tremendous noise, and with a disengagement of the same filamentous glass which will be noticed when we speak of the Isle of Bourbon.

Besides the volcano of Kirauea, which is in activity, there are several in an extinguished state. One of them, Mouna-Roa, is calculated by Captain King at 16,020 feet in height, estimating it according to the tropical line of snow. Another, Mouna-Kaah, the peaks of which are entirely covered with snow, cannot be less, he thinks, than 18,400 feet. Mr. Ellis reckons the height at between 15,000 and 16,000 feet.

Von Buch, from a comparison of a number of separate observations, estimates its height at only 12,693 French feet. He regards it as the focus of the volcanic forces that exist in the Pacific; and although now viewed as extinct, yet it is stated that the neighbouring mountain of Mouna-Wororay, the height of which is estimated at 10,122 feet, had an eruption in 1801 *.

The whole island of Owhyhee indeed, embracing a space of 4000 square miles, is, according to the observations of Mr. Ellis, one complete mass of lava, or other volcanic matter in different stages of decomposition. Perforated, he says, with innumerable apertures in the shape of craters, the island forms a hollow cone over one vast furnace, situated in the heart of a stupendous submarine mountain rising from the bottom of the sea; or possibly the fires may range with augmented force beneath the bed of the ocean, rearing through the superincumbent weight of water the base of Hawaiah†, and at the same time forming a pyramidal funnel from the furnace to the atmosphere.

Strzelecki (Desc. of New South Wales, page 106) remarks on this volcano, that labradorite, orthoclase and albite were all found as constituents of the same lava-current in Kirauea, within an area of four cubic feet. The same mass of rock

* Turnbull.

† I adopt the more usual method of spelling. Ellis in his late tour calls the island Hawaii.

too, which was close-grained basalt below, passed gradually into scoriaceous lava in its upper portions.

The islands of Revillagigedo, near the coast of Mexico, lie nearly in the same latitude, and being volcanic may perhaps connect the band of igneous operations going on beneath the Pacific with that of North America. Further south, nearly parallel with the equator, and with the volcanos of Quito, which will be afterwards considered, is the Galapagos group, of which Mr. Darwin has given us so interesting an account. It consists of five principal islands and of several small ones, all of which are volcanic, and on two of them craters have been seen in a state of eruption.

The craters are extraordinarily numerous, amounting perhaps to more than 2000, and are formed either of tuff, or of scoriæ and lava. The tuff is met with in two forms; the one friable, like slightly consolidated ashes; the other compact, with a lustre resembling resin, of a yellowish brown colour, and translucent. It is brittle, with an angular, rough, and very irregular fracture, and in hand specimens might be taken for pitchstone, although when examined on the large scale, its concretionary structure reveals its real origin. Mr. Darwin suggests, that the remarkable change which this material appears to have undergone since it was first deposited under water, may have arisen either from the action of heated water within the craters, or more probably from the admixture of the calcareous matter which penetrates it in thin seams.

I have already alluded (page 320) to a similar kind of tuff found in Iceland and Sicily, and called by Baron Walterhausen, who first described it in these two islands, palagonite. Professor Bunsen of Marburg has identified this rock with the one described by Darwin, and promises us a memoir on the nature and relations of this newly-recognised volcanic product.

The craters composed of tuff are for the most part broken away on their southern side, which is attacked by the united force of the trade-wind, and the swell propagated from the distant parts of the open ocean, here coinciding in their direction.

With regard to those craters that do not consist of tuff, their mineralogical constitution is basaltic, in which albite occurs in imbedded crystals associated with augite, and sometimes with olivine. One nearly-destroyed crater is made up of nine very thin seams of reddish brown vesicular basalt, with albite crystals, separated one from the other by equally thin beds of loose scoriæ. It is remarkable, that although the felspar is of the albitic species, pumice is absent. The barrenness of these islands however is quite in accordance with the refractory nature of albite, as compared with other species of felspar.

In the thirty-third degree of south latitude, about 110 leagues west of the coast of Chili, is the island of Juan Fernandez, which, according to Mr. Caldcleugh, is composed of greenstone and trap of various kinds, both amorphous and vesicular, containing olivine and carbonate of lime. The basalt is in some places almost columnar, and traversed by dykes. It would appear from this description as if the whole of the island was of submarine origin, and the volcanic forces no longer in action; but Mr. Darwin has stated*, that during the great earthquake of Chili in 1835, not only was this island more violently shaken than the opposite coast of the mainland, but a submarine volcano, which continued in action during the day and part of the following night, burst forth near Bacalao Head, where the depth was afterwards ascertained to be sixty-nine fathoms. The island was also affected by the earthquake of 1751, which overthrew Conception.

Returning now to the Polynesian Archipelago, we recognise in the group of the Society Islands a lofty trachytic cone, rising to a height probably not inferior to Etna, in the island of Otaheite. This is the mountain of Tobreonu, which is represented as extremely steep, and with a lake on its summit. The other islands are basaltic, but no active volcano appears to exist amongst them.

In the Friendly Island group however, a volcano is said, by Kotzebue, to have been seen burning in Toofua. It would seem, like Stromboli, to be in a state of continual

* Geol. Trans. vol. v. New series.

eruption, for Bligh, Edwards, and others have observed it burning. Other volcanos seem also to exist in the same group, as at Proby Island, and in that of Amargura or Gardner, where Captain Edwards observed traces of a recent eruption.

In the New Hebrides, the island of Tanna is stated, by Forster, to contain a very active volcano, as also the island of Ahrim in the same group.

South of the New Hebrides lies Matthew's Rock, drawn and described as an active volcano in the 'Voyage of the Astrolabe.' Maltbrun states that there is a volcano near Port St. Vincent in New Caledonia; but this Mr. Darwin believes to be an error, arising from a smoke seen upon the opposite coast by Cook, which disappeared at night. The probable existence of volcanos in New Guinea has been already noticed in my former chapter; but below the Salomon Islands a volcano was pointed out by the discoverer Mendana*, and Dampier observed one at the western entry of St. George's Channel in New Britain. He also mentions another on the east of New Britain near Cape Gloster, first perceived by Dampier, and again noticed by La Billardière in 1793.

From this statement it appears that volcanic action is still rife in various parts of the Pacific Ocean, included within north latitude 15° and 30°, and in south latitude below the parallel of 16°; but that there is an intermediate tract on either side of the equator, over which a number of low coral islands are scattered, entirely exempt from all indications of the kind, at least until we approach the shores of the American continent, where the Galapagos group make their appearance. These latter however, as well as the islands of Revillagigedo and Juan Fernandez, are so remote, that they may well be considered as belonging to another system, and hence we can more easily admit the view for which Mr. Darwin contends, that the tract alluded to is the seat of a vast subsidence, the rate of which may be supposed to keep pace in the main with the rate of growth which the coralline formations are experiencing.

This tract is in general avoided by navigators, from the

* Burney, vol. i. p. 280.

dangers arising from the numerous coral reefs which exist under water, as well as forming islands above it. From these rocks the latitudes to the north and south are in great measure exempt, showing that the formation of coral is in a degree coincident with the area of subsidence.

That the contrary process is going on where volcanic forces are, or have been in operation, has been inferred in the case of Otaheite, from Mr. Stutchbury having discovered near the summit of one of the loftiest mountains of Otaheite, at the height of several thousand feet, a stratum of semi-fossil coral. But Mr. Darwin regards it as very doubtful whether the latter was *in situ*, and is inclined to consider the elevation of this and the other volcanic islands belonging to the same group, as of great antiquity. Not so however the Sandwich Islands, the New Hebrides, the Friendly Islands, and others which have been noted as the seat of active volcanos, and which are surrounded by *fringing reefs*.

Here more unequivocal marks of recent upheaval are displayed, in the abundance of elevated corals and shells, apparently identical with living species that are everywhere discovered. Earthquakes also, a common cause of elevatory movements, as will be afterwards shown, are common in these portions of the Archipelago.

Between the New Hebrides and New Zealand lies Brimstone Island, which, from the high temperature of the water in the crater, may be ranked as active *.

New Zealand itself seems to be indebted to volcanos for much of its formation. The southern and middle islands indeed have as yet been but little explored, but in the northern we recognise an active vent in Mount Egmont, a mountain no less than 8829 feet in height, according to Dieffenbach, which rises from a table-land, and consists of clinkstone covered over on the summit with scoriæ.

In the north of this same island, we may consider the whole tract to the westward and northward of the Bay of Islands as a volcanic table-land. The lake Maupère seems to be a crater broken away on its western margin. Its lavas resemble, in the freshness of their appearance, those of Au-

* Berghaus, Vorbemerk. ii. lief, § 56.

vergne, and thermal waters are abundant in its neighbourhood.

Near Auckland also are several volcanic cones. Rongitoto is a volcanic island, with a crater about 150 feet deep. Between Waitemata and Manukao, a number of cones of extinct volcanos rise above the table-land; they are strewed over with scoriæ, and sometimes still retain vestiges of a crater.

Near Maunga-Tautari the thermal waters appear scarcely less interesting than the geysers of Iceland. They send forth jets of water to a height of eight or ten feet, depositing alum and sulphur, and exhaling a slight smell of sulphuretted hydrogen. Near them the mud is raised to a temperature exceeding that of boiling water, or to 216°.

It is however round about the mountain of Tongariro, which rises to the height of 6200 feet, that the connexion between hot springs and volcanos is most manifest. This mountain may be regarded as an active volcano, if the constant emission of steam from a crater be a sufficient indication, for such appears to be the case from the report of Mr. Bidwell, who first ascended it.

He describes the cone as consisting of loose scoriæ; but there were from time to time emissions from it of hot water and mud, which poured down the mountain, coupled with ejections of steam and of black smoke, with a noise like that of a steam-engine, but no lava or scoriæ.

White Island, in its neighbourhood, is a solfatara continually evolving sulphur, and in all directions round are numerous hot springs, many of a boiling temperature, and depositing silex, like those of Iceland, as well as magnesite. This latter fact is new, and might lead to some curious speculations.

The margins of the lake Taupo, which seems to have been formerly a crater, consist of trachyte, and the mountains near are of leucitic lava. There seems indeed to be a line of volcanos ranging from N.E. to S.W., in which Mount Egmont, Lake Taupo, Tongariro, and the hot springs are situated.

Chatham Islands, which lie a little to the eastward of New Zealand, are stated by Dr. Dieffenbach to be volcanic*.

* Geogr. Journ. vol. xi. new series.

Many of the mountains have a pyramidal form, strongly indicative of their origin, and they are composed of basalt either compact or cellular; and in the latter case, with the cavities sometimes empty, and at other times filled with carbonate of lime.

In Van Diemen's Land no active volcanos occur; but Mr. Darwin observed on the west side of Storm Bay, that the sandstone strata were capped by streams of basaltic lava with olivine, close by which was a mass of brecciated scoriæ containing pebbles of lava, which probably marks the place of an ancient submarine crater. Two of these streams of basalt were separated from each other by a layer of argillaceous wacke, which could be traced passing into partially altered scoriæ. Strzelecki * has attributed the fossilization of the opalized trees, described by Dr. Hooker, to the lava injected into them subsequently to the period of the variegated sandstone formation.

Craters of extinct volcanos have likewise been recognized in Australia, by Mr. Russell†, near Brisbane, in latitude 27°.

Mr. Jukes too, in a letter with which he has favoured me, states, that the eastern coast of Australia for 2000 miles, from Endeavour Strait to Jervis Bay, has pumice pebbles strewed along it, never at any great height above the sea, and sometimes imbedded in the recently formed coal and other conglomerates of that coast. He also mentions, that cellular trap, or lava in horizontal strata, occurs as the most recent rock in the district of Port Philip, where my friend Dr. Melvill, who visited many parts of New South Wales on his voyage homewards from that country, informs me that he recognized the existence of several perfect, though extinct craters, from which streams of lava, probably the same as those alluded to by Mr. Jukes, may be distinctly traced as having proceeded.

The crater he visited was not far from Mount Macedon, near the range of the Plenty, and went by the name of Crater Mount, being about thirty miles from Port Philip.

* Physical Description of New South Wales, p. 146.

† See Russell in Geogr. Journ. vol. xv., and likewise a Paper by Mr. Cunningham in the 'Proceedings of the Geological Society,' vol. ii. p. 109.

It rose from a level plain, over which were scattered several little mammilloid eminences, consisting of volcanic matter. The crater was situated in the centre of a conical mountain; it was 700 feet deep on its northern side, but much lower than its southern, and its internal diameter was about 600 feet. There was a gulley on its north-western side. It was composed of scoriæ; but these were either so decomposed, or so intermixed with other products, as to allow of vegetation, for the interior was thickly wooded.

In Torres Strait, Murray Islands, Darnley Island, and Bramble Key are stated by Mr. Jukes to be of volcanic origin, consisting partly of conglomerates and sandstones made up of the detritus of lava, with which is associated a limestone, probably that of the great coral reef, through which these rocks have forced their way.

Strzelecki* also has pointed out the irruption of greenstones and basalt in parts of the Australian Alps behind Sydney, but this must have taken place during the secondary period. Mount Hay, 2400 feet in height, is capped by basalt; but Mount Kosciuszko, which rises 6500 feet above the sea, is of syenite. These lofty mountains however seem to form an exception to the general character of this vast continent, which, like that of Africa, would appear to be destitute of volcanos in its interior, and hence to possess a general equality of surface, and consequently to be unprovided with great rivers and without any capabilities of improvement.

We must not confound with real volcanos the pseudo-volcanic appearances presented by Mount Wingen, lat. 31° 54′, long. 150° 56′, the Burning Mountain described by the Rev. Mr. Wilton, chaplain at Newcastle, which arise evidently from the combustion of coal †.

The lowest point ever reached by man within the southern hemisphere was south latitude $77\frac{1}{2}°$, where nearly in the same longitude as New Zealand, a vast extent of continent, since called Victoria Land, was discovered by Sir James Ross in his exploring expedition, 1841. Here two volcanos were ob-

* Phys. Descr. of New South Wales, pp. 56 & 120.

† Journ. Geogr. Soc. vol. ii. 1832.

served, the one extinct, called Mount Terror, the other in a state of great activity, called Mount Erebus.

The latter was estimated at no less than 12,600 feet above the level of the sea, and makes part of a stupendous chain of mountains, belonging to a new continent of vast but undefined extent, the whole mass of which, from its highest point to the ocean's edge, is covered with everlasting snow and ice *.

This icy barrier, running east and west on this parallel, forbids any further progress towards the pole, or any nearer examination of the igneous phænomena there displayed.

* I cannot help quoting the remarks made by Dr. John Hooker in a letter to his father, published in the 'Journal of Botany,' on this wonderful spectacle:—

"The water and the sky were both as blue, or rather more intensely blue than I have ever seen them in the tropics, and all the coast one mass of dazzlingly beautiful peaks of snow, which, when the sun approached the horizon, reflected the most brilliant tints of golden yellow and scarlet; and then to see the dark cloud of smoke, tinged with flame, rising from the volcano in a perfect unbroken column, one side jet-black, the other giving back the colours of the sun, sometimes turning off at a right angle by some current of wind, and stretching many miles to leeward! This was a sight so surpassing everything that can be imagined, and so heightened by the consciousness that we have penetrated, under the guidance of our commander, into regions far beyond what was ever deemed practicable, that it caused a feeling of awe to steal over us, at the consideration of our own comparative insignificance and helplessness, and at the same time an indescribable feeling of the greatness of the Creator in the works of his hand."

CHAPTER XXVI.

ISLANDS ON THE EASTERN COAST OF AFRICA.

Madagascar.—Mauritius—basaltic rocks—recent lava-currents.—Isle of Bourbon—extinct volcano of Gros Morne—active volcano—filamentous pumice.—Volcanic rocks to the South of Africa.—Crozet Islands.—Kerguelen's Land.—Islands of St. Peter and St. Paul.

In the preceding chapter I laid before you an account of the volcanic phænomena that occur in that vast tract of ocean bounded by the western coasts of America, by the eastern coasts of Asia, and by the continent of New Holland. I shall next proceed to state what volcanos have been recognized in the islands that exist between New Holland and the eastern coast of Africa.

The principal of these are, the great Island of Madagascar, the Isle of Bourbon, and the Mauritius, the first of which has been too little explored to allow of my announcing with certainty anything respecting its physical structure *, but of the two others, we are indebted to Bory St. Vincent for a geological sketch, and some particulars respecting the Mauritius have been more recently contributed by Mr. Darwin.

The Mauritius is of an oval shape, about eleven leagues in ts greatest length, and eight in its greatest breadth; it rises on all sides from the circumference to the centre, so as to form a conical mountain, called Le Piton.

The other mountains, of which the most elevated is Peter Botte, constitute a chain extending across the island, and all consist of volcanic matter, namely either of basalt or of lava †.

* Madagascar is stated by Daubuisson to contain volcanos, on the authority of Ebel (Bau der Erde, tom. ii. p. 289), who reports, that in this island there is a volcano ejecting a stream of water to a sufficient height to be visible twenty leagues out at sea. Sir Roderic Murchison, Dec. 1827, exhibited at the Geological Society some specimens of a volcanic nature said to have come from this island, but the locality was not mentioned.

† Peter Botte was considered inaccessible till the 7th of September 1832,

The basalt is sometimes prismatic, and intersected by dykes. It constitutes the skeleton, as it were, of the island, and rises to the height of between 2000 and 3000 feet in the mountains near Port Louis. The general inclination of the beds is towards the sea.

The lavas, on the contrary, seem to have flowed into the valleys between these rugged basaltic mountains, forming a plain, raised probably about 1000 feet above the sea.

From the representation given by M. Bailly, as quoted with apparent approbation by Darwin, it would seem that the basaltic mountains form a series of ramparts extending, with some interruptions, all round the coast, with their strata inclined towards the sea, and their escarpments facing on all sides the centre of the island.

Within this ring of basaltic matter occur those streams of lava which have overspread so much of the interior, so that M. Bailly boldly supposes, that the hollow was formed by the sinking in of the whole upper part of one great volcano.

The low region to the north, and the isolated rocks off the coast, consist of a coralline limestone, produced at a very recent epoch. It would seem to have been but lately covered by the sea, which consequently reached the base of the basaltic mountains rising up from it. Several authors indeed have described masses of upraised coral-rock extending round the greater part of the circumference of the island.

The island of Bourbon, like the Mauritius, slopes on all sides upwards towards its centre.

It may be viewed as consisting of two volcanic mountains of different dates; the south-eastern, which is the smallest, still in a state of activity; the north-western, extinct; the point of contact between the two coinciding with a line drawn from N.E. to S.W., along which the country is of inferior elevation.

The mountain of Gros Morne is the most elevated and centrical point of the extinct volcano, and is estimated by Bory St. Vincent at 1500 toises. It consists of steep ridges, either of compact basalt often columnar, or of porous lavas

when Lieut. Taylor, R.A., succeeded, by means of a ladder and ropes, in scaling its precipitous sides. (Journ. of the Geogr. Soc. vol. iii.)

and scoriæ. Its escarpments exhibit a number of basaltic dykes, which, it is to be remarked, are never observed in the one now in activity. Some of these dykes seem no larger than cords, whilst others are of the same thickness as the beds which they traverse. They penetrate indiscriminately all the rocks, sometimes in a direction perpendicular to their planes, at others in one more or less oblique. They also intersect each other in the figure of the letter X. They are usually divided into prisms, which, whatever may be the inclination of the dyke, range at right angles to it. Being more compact than the lavas they penetrate, they frequently stand out in bold relief.

It is worth observing, that earthquakes are only experienced in that part of the island which is farthest from the site of the active volcano, and even there but rarely.

The active volcano, situated in the south-eastern extremity of the island, is one of the most considerable yet observed. Its height, as estimated by M. Berth, is 7507 French feet. It is surrounded by a number of cones with craters, from which lavas and elastic vapours have from time to time proceeded; but on its summit are two craters, called by Bory the Crater Dolomieu and the Crater Bory, both active vents at the time of his visit.

Betwixt them is a conical protuberance of lava, called by Bory the Mamelon Central, 160 feet in height, with a hollow in its centre eighty feet deep. It seems composed of a number of little streams of lava, which were poured successively from the aperture in the centre. From 1783 till 1801, it has been stated, that each year at least two streams of lava have issued from the flanks of this volcano*, and eight of them have extended to the sea-coast.

The lavas appear to contain much glassy felspar, so that they are probably trachytic; and although pumice of the ordinary kind is not mentioned, yet obsidian has been found, as well as a very curious substance like spun glass, which may be regarded as intermediate between pumice and obsidian, since it partakes of the filamentous character of the one, and the vitreous texture of the other.

Bory St. Vincent describes the quantity of these films as

* Bory, vol. ii. p. 320.

being on one occasion sufficient to form a cloud, covering the entire summit of the volcano. Scarcely had he observed it, when the whole party found themselves covered with small shining and capillary flakes, possessing the flexibility and appearance of silk, or of a spider's web. This substance was accompanied with showers of light, vitreous, spongy scoriæ, in fragments varying from the size of a cherry to that of an apple. It fell into powder on the application of the slightest force.

The threads, of which we have just been speaking, appeared to him nothing but a modification of the scoriform lava peculiar to the Isle of Bourbon. He supposes they may have been formed, owing to the extrication of elastic matter from this substance, whilst in a state of partial fusion, on the same principle that threads are formed in sealing-wax, when the stick is suddenly withdrawn from the surface of a portion, dropped upon paper, and not completely cooled. He was confirmed in this opinion by observing, attached to these threads, little pear-shaped globules, which were found on examination to be identical with the vitreous scoriæ before alluded to *.

In the same longitude nearly as the Isle of Bourbon, but twenty-seven degrees nearer to the south pole, are the Crozet Islands †, all of which are volcanic. The mountains rise in peaks and cones to an elevation of 4000 to 5000 feet, and are of the wildest and most rocky aspect.

Kerguelen's Land, near it, is stated also to be volcanic, though, like the Faroe Islands, it contains seams of coal imbedded; and the islands of St. Peter and St. Paul both contain craters, of which the latter is said by the compiler of the voyage of the Entrecasteaux to have exhibited signs of activity, when the vessel passed it ‡.

* Similar products have been noticed as occurring in the island of Guadaloupe, and by Mr. Ellis in Owhyhee. See his Tour in the Sandwich Islands: London, 1826.

† Hooker's 'Botany of the Antarctic Voyage,' Introduction.

‡ See Malte Brun, vol. iv. p. 455, who states that the island of St. Paul has been confounded by some writers with that of Amsterdam.

CHAPTER XXVII.

AFRICAN CONTINENT.

Volcanic appearances in Kordoufan—Fezzan and Tripoli—Algeria—Mount Atlas—Western coast.

BEFORE proceeding to the islands in the Atlantic Ocean that lie on the western side of Africa, it will be well to point out what traces of igneous action have been discovered, either in that great continent itself, or in those small islands which may be regarded as its immediate dependencies.

It would seem that in the province of Kordoufan, in Nubia, a chain of extinct or half-extinct volcanos occurs in lat. 14°. Rüppell, on whose authority the whole depends, does not appear to have visited them personally. The account he gives of them in his 'Travels in Nubia' is as follows:—

To the south and south-west of Obeid, about fifteen leagues distant from that town, commences a chain of hills which seems to be of volcanic formation. From the information received, it would seem that the rock is very different from that of the northern hills; it is partly like glass, and quite black, being probably obsidian, partly brittle and full of round holes. A thermal spring is found there: from a mountain which is without vegetation, sulphureous vapours arise.

Rüppell was even shown sulphur in small stalactitic concretions apparently formed by vapours that had been sublimed. It is not unusual for noises to be heard proceeding from the interior of the mountain, and for earthquakes to be experienced.

These facts seem to show the existence of an active or semiactive volcano, but the communication with the country being interrupted, Rüppell was unable to satisfy himself on the point.

M. Jomard also, who accompanied Buonaparte in his invasion of Egypt, states, that in the centre of that country,

between the Nile and the Red Sea, in the midst of the alabaster quarries, there exists a mountain called Djebel Dokhan, which means the Mountain of Smoke. The Arabs speak of the petroleum observed to flow some distance off. Djebel Kebryt, or the Sulphur Mountain, lies more to the south, in the 24th degree of latitude, and on the borders of the sea. According to the reports of the Arabs, Djebel Dokhan smokes continually.

It is probable that Rüppell and Jomard may both refer to the same chain of mountains, and as their distance from the sea is very great, it would be of great importance to the theory of volcanos to ascertain whether or no they really contain an active vent.

It must however be remarked, not only that neither reporter has visited the spot to which he refers, but that it is not stated even on the authority of the Arab informants, that lava had been ejected from any of the mountains specified.

In Abyssinia also it is stated, on the authority of certain recent French travellers*, that volcanic products are to be seen in the islands near the coast, and on the shores themselves. These authors consider it probable that there were volcanos there antecedently to the period at which the Ptolemies founded settlements on the coasts; but it is not certain that any now exist in Abyssinia, the springs of hot water they observed upon the shore not deciding the question, although some of them reach 64° or 65° Cent. and even exceed that temperature.

Many travellers, it is true, affirm that they have seen volcanos on the coasts of Choa. M. Rochet in particular has mentioned the volcano of Dofano (a mountain situate in the vicinity of Angobar), and has figured it as being in a state of activity; but MM. Galinier and Ferret are of opinion that M. Rochet may have mistaken fumaroles for volcanic eruptions, seeing that the Abyssinians appear to have no notion of volcanos.

On the northern coast of Africa I know of no active volcano,

* MM. Galinier and Ferret, l'Institut, No. 547. p. 210.

nor have even any rocks of an igneous character been pointed out to us, excepting some in Fezzan and Tripoli, where Captain Lyon speaks of a formation of that kind associated with calcareous beds, which, according to Dr. Buckland, belong to the tertiary series; in the Nubian desert, sixty-nine miles from Syene, and in the desert between Cairo and Suez, where Lieut. Newbold* however considers, that what intrusive rocks occur are of submarine origin and of great antiquity; and in Algeria, where the remarkable hot springs of Hammam-Mascoutin, three-quarters of a league above M'jiz-Amar in the province of Constantine, bespeak the presence of volcanic action. The temperature of the highest of these is 76° Reaumur; they smell of sulphur, and deposit carbonate of lime, which forms little conical hillocks round the spring, from twenty-five to thirty feet in height, presenting a remarkable appearance.

In the chain of Mount Atlas there are some mountains called Black Harutsch, which are conjectured to be of an igneous character.

Humboldt describes the group as consisting of basaltic rocks of a grotesque form. It was (he says) the Mons Ater of Pliny, and on its western range, where it is called the Mountains of Soudan, it has been explored by Ritchie. These erupted masses of basalt in a tertiary limestone—this range of hills elevated like walls upon the beds they cover—bring to one's recollection, he says, the basaltic eruptions of the Vicentin. Hornemann moreover found, in the most recent calcareous formations of the Harutsch group, petrified fish as at Monte Bolca. Ritchie and Lyon have observed that the basalt in these mountains is intimately mixed with carbonate of lime, as in the Monte Berici, and the latter notes the occurrence of dolomite.

Now it is rather confirmatory of the volcanic nature of this or of some other chain connected with the Mount Atlas, that the Greeks regarded the whole of the coast of Africa beyond the Pillars of Hercules as thrown into disorder by the fire of volcanos, and that Solinus expressly speaks of the snowy summit of Mount Atlas as glittering with nightly flames; from

* See Proc. Geol. Soc. vol. iii.

whence we might be led to infer, either that the mountain so called was situated in one of the islands of the Hesperides, being probably identical with the Peak of Teneriffe, or that some volcanic appearances exist in the chain which the moderns designate as Mount Atlas.

In the account of the Periplus of Hanno, as well as in that of Eudoxus, as quoted by Mela (which is considered a fabrication and a direct copy of the former), we read, that as these navigators were coasting in the above direction along this part of Africa, torrents of light were seen to fall on the sea; that every night the shore was covered with fires; that the Great Mountain, called the Car of the Gods (θεων οχημα), had appeared to throw up sheets of fire that rose even to the clouds; and that the sand on the shore was intolerably hot.

Now the mountain that went by this name is placed by Polybius south of the town of Lixus, a Carthaginian colony that lay beyond the Pillars of Hercules, and in the midst of the chain of Mount Atlas. Nor is it probable that this ancient navigator should have deviated so far from the coast, as would have been necessary, in order to enable him to catch a glimpse of the volcanic fires of Teneriffe.

It is remarkable indeed that the ancients, although they have described the Canaries under the names of Canariæ, Purpurariæ*, and Fortunate Islands, seem to have taken no notice of the volcanos that occur there. Even the Peak of Teneriffe is only alluded to in the mention of the perpetual snow found upon it, from whence the island obtained the name of Nivaria.

It is therefore most probable that the description of Hanno refers to the continent of Africa, and not to its islands; but before we decide that anything of a volcanic nature is hinted at, we ought to recollect that the custom † which exists there, as in many other hot countries, of setting fire at certain seasons to the forests and dry grass, might have given rise to the statements of the Carthaginian navigator. Even in our own

* Bory St. Vincent thinks that by the Purpurariæ, Madeira and Porto Santo were intended.

† This is the opinion of the Abbé Gosselin in his 'Géographie des Anciens.'

times the island of Amsterdam was set down as volcanic from the very same mistake.

M. Douville, in his journey into the interior of Africa, discovered some traces of volcanos behind the Portuguese settlements on the Congo or Zairè river. The provinces of Ambacca and Pongo Andouja he describes as extraordinarily rent by volcanic action now extinguished.

Between 3° and 5° of south latitude, and 29° and 30° east longitude, he also observed a great lake (perhaps the Lake Maravi of our maps) in all respects resembling the Lake Asphaltites in its properties, and surrounded by mountains of a dark-coloured and fœtid kind of stone.

Further to the south, northwards of Sierra Leone, the Isles de Los* are of volcanic origin, being formed of hard, blue and iron-coloured lava, with occasional masses of porphyritic hornstone. Many other parts of this coast, according to Captain Belcher, exhibit traces of igneous action, but from the account given, we should be led to expect that the rocks were chiefly of a basaltic character.

The islands of Amboises near Fernando Po are also stated by Captain Allen† to be volcanic, and Fernando Po itself seems to be similarly constituted.

* Captain Belcher in the Journal of the Geographical Society, vol. ii.

† Journal of the Geographical Society, vol. xiii. Captain Allen supposes this to be the Car of the Gods mentioned by Hanno.

CHAPTER XXVIII.

ISLANDS LYING TO THE WEST OF AFRICA.

Canaries.—Teneriffe, its basaltic rocks, trachytes, lavas.—Palma, its Caldera.—Great Canary—Fortaventura—Lancerote—Madeira—Porto Santo.—Azores—St. Michael—Terceira—Flores—Graciosa—Atlantis of the ancients.—Cape Verde Islands—Fuego—St. Jago.—Islands south of the Equator—Ascension—St. Helena—Fernando Noronha—Tristan d'Acunha.

The volcanos occurring in those groups of islands which lie at a certain distance from the western coast of Africa, in the midst of the Atlantic Ocean, deserve a separate consideration. Here at least the most unequivocal proofs of existing igneous operations manifest themselves, although feeble, as compared to those, which their geological structure shows to have been carried on there in antecedent periods.

The whole group of the Canaries, for example, seems to be placed, as it were, within the sphere of the same submarine volcano; for although vestiges of other rocks are to be met with, as granite and mica-slate in Gomera, and limestone in the Great Canary, Fortaventura and Lancerote, yet none of these islands are exempt from occasional manifestations of the same igneous action.

The most remarkable phænomena arising from the above cause occur in the island of Teneriffe, where the lofty peak of Teyde, though tranquil at present on its summit, still exhibits on its flanks occasional evidences of the same volcanic action, from which the rocks composing its colossal structure seem wholly to be derived.

In considering this island, we must in the first place distinguish between the productions of the actual volcano and the range of basaltic rocks surrounding it. The latter do not rise to a height of more than 500 or 600 toises, whilst the elevation of the peak itself is, according to Humboldt, 1909 toises*.

* That is (reckoning the toise at 6 feet 4 inches English) 12,090 feet.

It is through the midst of this basaltic formation that the rocks constituting the principal mass of this volcano have been protruded, and hence we may characterize the two classes under the name of ancient and modern lavas, just as has been done in the case of those which are found at the foot, and which compose the mass of Mount Etna.

The modern lavas however of the peak admit likewise of a twofold division, first, into those composing the nucleus of the mountain, which are of a trachytic character, and appear to have been forced up through the midst of the older basalts; and secondly, into the products of the volcanic action to which this central mass furnished an appropriate vent.

The latter are very various in their nature and characters: we may distinguish, first, the lavas, which have sometimes a stony, and sometimes a vitreous aspect; and secondly, the loose ejected masses, such as pumice, obsidian and lapilli.

Of the lavas, such as have a stony aspect appear to be confined to a comparatively low elevation, and to have proceeded exclusively from the flanks of the volcano, whilst the vitreous are found only near the summit, the lowest point at which they occur being 8900 feet above the level of the sea.

The source of the latter description of lavas appears to have been the adjoining mountain Chahorra, which holds the same relation to the peak, that the Monte Rossi do to Mount Etna, being a sort of appendage to the principal volcano, and produced by one of its lateral eruptions.

Humboldt nevertheless mentions one stream of vitreous lava as having been traced to the very summit of the peak, where there exists a circular cavity, which must be considered at present in the light of a solfatara rather than of a crater, as it is never known to emit flames, though sulphureous vapours constantly arise from it. It would appear, however, that it has in former times given vent, not only to the stream of lava above noticed, but likewise to showers of pumice and obsidian, loose masses of which strew all the upper part of the mountain.

The latter description of ejected masses does not appear to extend to the lower parts of the mountain, the surface there being mostly covered by lapilli, consisting of black lava, pos-

sessing more of a stony aspect, not mixed with either obsidian or pumice.

This latter distribution, says Humboldt, seems to confirm the observation made a long time ago at Vesuvius, that the white ashes are thrown out last, and indicate that the eruption is at an end. In proportion as the elasticity of the vapours diminishes, the matter is thrown to a less distance; and the black lapilli, which issue the first, when the lava has ceased flowing, must necessarily reach farther than the white lapilli. The last appear to have undergone the action of a more intense fire.

The size of the crater that exists in the summit of the peak is diminutive compared with that of Etna or of Vesuvius, being only 300 feet in its greatest, and 200 in its lesser diameter, whilst its depth does not exceed 100 feet.

Indeed it may be remarked in general, although the rule is liable to exceptions, that the dimensions of a crater are in an inverse ratio to the elevation of the mountain; for in proportion to the height which the ejected masses must attain before they reach the orifice, will be the resistance to be overcome in forcing a passage by this channel; so that in a mountain like the Peak of Teneriffe, the force applied will in most instances be instrumental in creating apertures in the flanks of the mountain, rather than in enlarging the cavity on its summit.

The existence nevertheless of this chimney preserves the island, in Von Buch's opinion, from those destructive eruptions which convulse some of those adjoining it, since elastic vapours, the immediate and necessary concomitants of volcanic action, thus find a readier vent, and confine their violence to the immediate precincts of the volcano.

We must not however go so far as to suppose, that Teneriffe itself is altogether exempted from those convulsions of nature which are so common in the neighbouring islands.

Its lofty peak, although it may act as a safety-valve, and moderate the violence of the volcanic action by determining it to a point at which it can obtain a vent, proves nevertheless from this very circumstance a dangerous neighbour to the towns that lie underneath it. In the years 1704 and 1706, lateral eruptions took place from the Peak, the latter of which

destroyed the port of Garachico, the finest and most frequented harbour in the island. In 1798 too, the mountain Chahorra threw out lavas and scoriæ for the space of more than three months, and the violence of the eruption may be judged of by the fact mentioned by Humboldt on the authority of an eye-witness, namely that considerable fragments of stones were thrown to such a height, that from twelve to fifteen seconds were reckoned during their descent. This curious observation proves that the rocks projected from this crater rose to a height of 3000 feet and upwards.

Before I conclude the subject we are upon, I may remark, how strikingly the difference between the volcanic products of Teneriffe illustrates the manner in which the effects of heat are modified in such cases by the influence of pressure.

At the bottom of the mountain are the basaltic lavas or tuffs, which being produced probably under the ocean, and at a very remote period, are compact and possess a stony fracture. Through these have been protruded the trachytes of the peak, which, having had the resistance of so large a body of rock to overcome, also possess a considerable degree of compactness.

This conical and upheaved mass, having become the centre of the volcanic operations subsequently carried on, is surrounded by products of later formation, some of which were ejected from the summit, at a time when a free channel of communication existed between it and the interior of the volcano; others from the flanks at a later period, when the aperture had become obstructed by the falling in of its sides, or the accumulation of ejected substances. It is clear that in either of these cases, the pressure exerted upon the substance whilst in a melted state was less considerable than that which prevailed during the formation of the submarine lavas, or even of the trachyte, and hence it is found to possess more of a vitreous aspect, and to be more completely penetrated with cells*.

The remainder of this group, as described by Von Buch†,

* The pumice never covers any of the currents of lava,—a proof of its greater antiquity. See Von Buch, in Leonh. Min. Tasch. part iv. 1823.

† See the Transactions of the Royal Academy of Berlin for the valuable

appears to consist of submarine lavas, similar to those which I have described as forming the basis of the island of Teneriffe. The strata of which they are constituted lie in such a position, that they would seem to have been elevated from the bottom of the ocean by the force of elastic vapours; for they dip away in all directions from some central point, where a crater still exists to attest the former agency of aëriform fluids.

This peculiar structure is best illustrated in the island of Palma, where one of those deep valleys called *Barancos* exposes an excellent section of the alternating beds. Amongst them Von Buch distinguished one of basalt containing augite and olivine, covered by a stratum of rolled masses chiefly of the same material. Repeated alternations occurred to him as he proceeded, between beds of this conglomerate and continuous strata of compact or amygdaloidal basalt, and below them all was a single bed of trachyte, the only rock of a clearly felspathic nature that is found. Its basis is of a dark grey colour, and is made up of an infinite number of very small tessular concretions, arising from the separation effected in the mass of the stone by a multitude of minute drusy cavities distributed everywhere over. These hollows are in general only partially filled, but contain chabasite, analcime and other crystals. Glassy felspar is met with in the rock in long narrow crystals, which generally run in parallel lines, unless when the drusy cavities before mentioned interfere with their direction.

These beds are all intersected by dykes of granular basalt, which become more and more abundant as we proceed along the valley, until at length the lofty wall of rock which bounds it is covered with a network of them.

They all alike rise towards the crater, or, as it is called by the people, the Great Caldera, a circular opening in the centre of the island, which is stated by Von Buch to exceed 5000 feet in depth, whilst its diameter probably is in most parts as much as two leagues, so that it embraces an area, such perhaps as exists in no other volcano of the globe, conjoined with so great a depth. From its brim we are en-

memoirs of Von Buch—on Craters of Elevation and on the Island of Lancerote, 1818–19, now embodied in his Description of the Canary Islands, so often referred to.

abled to look down upon the abyss, and observe underneath us the terminations of the strata, which we have successively passed in our way to it. Viewed from this point they all appear horizontal, but this, as I observed in speaking of the Monte Somma, is an illusion, and arises from their terminations only being visible, and from their ranging at an equal elevation in every part of the circular wall which bounds the internal cavity of the crater.

The Caldera of the isle of Palma, says Von Buch, differs much from the crater of an ordinary volcano. Here are no streams of lava, no slags, no lapilli or ashes. Nor do we ever find the latter of such a circumference, or so profound and abrupt. Its general aspect seems to show, that it was formed by the pressure of those elastic fluids which raised the whole island above the level of the ocean, and changed the strata composing it from a horizontal to their present highly inclined position. The aspect of the *barancos* is such as favours this hypothesis; these valleys are too narrow and abrupt to be attributed to diluvial action, and are so devoid of water that they cannot be referred to torrents; but if we suppose a succession of solid and unelastic strata to be suddenly lifted up in the manner of those in the island of Palma, it is evident, that not merely would a central aperture be formed where the crater now exists, but that the strain would occasion a number of lateral fissures corresponding with those called in the island *Barancos*.

The deep ravine which extends from the crater to the foot of the cone, called the Baranco de las Angustias, is not peculiar to the island of Palma; only that in those cases where no more than the upper brim of the crater rises above the level of the ocean, as more commonly happens, the sea-water enters through the fissure, and converts the crater into a circular bay, just as is shown in Barren Island, page 413. In Palma this has not occurred, because the bottom of the Caldera itself stands above the surface of the sea.

The structure of the island of Great Canary is very similar to that of Palma,—the same heaving up of the strata round a central point, the same deep and abrupt barancos, the same description of crater exhibiting the successive outcrops of the adjoining beds.

The order of superposition in the latter is such as to illustrate apparently the gradation that often occurs in the character of volcanic products, and perhaps the manner in which they have been derived by successive changes from the fundamental granite. Lowest of all Von Buch descried the primitive rocks; then masses of trachyte; afterwards an aggregate consisting of angular fragments of the latter, forming either a conglomerate or a tuff, which alternate with one another several successive times; still higher a rock, composed of augite and felspar (dolerite), interstratified with beds of rolled masses of the same composition, but of a cellular structure; then an amygdaloid; and last of all basalt.

Section of the Crater of Elevation in the Isle of Great Canary.

The structure of Fortaventura is also similar, but Lancerote, though originally raised up in the same manner as the other islands, has since been augmented by the eruptions of volcanic matter that have subsequently taken place upon its surface. Lancerote is distinguished from the other Canary Islands by its comparative flatness, possessing neither those lofty precipices nor those abrupt conical hills that occur in the rest. It affords indeed an example of an island exhibiting in all its parts the most decided evidence of volcanic action, but yet destitute of any one elevated conical mountain with a crater to which these effects could be traced. There is nevertheless in one corner of it a vestige of the same kind of crater which I have just been noticing, but here, owing probably to a part being sunk in the ocean, the strata are only seen rising on the side which faces the water.

Von Buch has given a striking description of the aspect of that portion of the island from whence proceeded the lava which in the year 1730 caused so much devastation.

After a painful walk, he says, over a tract of harsh, undecomposed lava, I reached at length an eminence composed entirely of an accu-

mulation of slag and lapilli, which were heaped in successive layers upon each other. In the centre was a crater walled in by precipitous rocks, of which one side was broken away by a lava which had proceeded from its interior. Within the compass of this hollow two other minor craters appear, which emitted at the time volumes of aqueous vapour mixed with sulphureous exhalations. Hence it is that the hill has obtained the name of Montagna di Fuego.

It is impossible, continues Von Buch, to describe the scene of desolation which presents itself from the summit of this crater. A surface of more than three square miles in a westerly direction is covered with black lava, in the whole of which space nothing occurs to break the uniformity of the prospect, but occasional small cones of basalt scattered over the plain.

It is clear that this vast mass of lava is not derived from any one point, even the Montagna di Fuego appearing to have contributed but little to its formation, for the lava actually proceeding from the latter is found to take an easterly instead of a westerly direction. During my ascent I felt very anxious to ascertain what the other sources might be which assisted in emitting so vast a mass of lava. How much was I astonished, when on reaching the summit I perceived an entire series of cones, all nearly as lofty as the Montagna di Fuego, placed exactly in a line, the nearest covering the farther ones in such a manner that the summits of the latter were alone seen peering from behind!

Between the western coast and the little village of Florida I counted twelve cones of larger size, of which the Montagna di Fuego was the sixth in the series, besides a considerable number of smaller cones, partly between and partly on the side of the larger ones. It was an exact repetition of the phænomena of Jorullo, or of the Puys in Auvergne. The whole of this eruption proceeded in all probability from a large fissure, the existence of which is in all cases found to produce effects of the more alarming kind, the more distant it is from any volcano, the latter serving as a sort of chimney for the escape of the matter within.

On my road to Florida I visited several such cones. They all alike consist of heaps, 300 or 400 feet in height, of harsh, porous, sharp lapilli of the size of a bean, which cause a grating sound when they roll upon each other.

These craters open for the most part towards the interior of the island, where the streams of lava unite to form one vast continuous bed, which, the farther we trace it from its source, is found to be less and less charged with olivine.

The larger part of these effects is to be attributed to the great eruption, or rather series of eruptions, which took place in this island between the 1st of September, 1730, and the 16th of April, 1736. The details are given in the interesting memoir by Von Buch which has been already referred to, but it would be inconsistent with my plan to do more than particularize some of the leading features.

A number of rents took place successively in the island, generally occurring in the same direction*. From these issued in all cases flames and smoke, and in the majority loose fragments of volcanic matter and streams of melted lava. The former, accumulating round the apertures from which they were ejected, often formed conical hills of considerable height; the latter, taking different directions, ravaged various parts of the island, and in general continued to flow on until stopped by the sea. In one case the lava was diverted from its original direction by a huge rock which suddenly rose in the midst of it, but of which no vestiges are to be seen at present. Gaseous exhalations likewise were emitted, which proved fatal to the cattle. At length the inhabitants, wearied out by such a series of misfortunes, seeing the most fertile parts of their country successively reduced to irretrievable ruin, and despairing that the eruptions would ever cease, determined on leaving their homes, and took refuge in the neighbouring island of Great Canary.

One of the most curious phænomena attendant on this eruption, though one not altogether peculiar to it, was the rise of flames from the midst of the sea. The nature of these is worth inquiring into, as it may hereafter assist us towards a theory of volcanos.

The only gas at present known, which inflames spontaneously at ordinary temperatures on the surface of water, is phosphuretted hydrogen, and this can hardly be suspected, as the product of its combustion is phosphorous acid, a substance which is possessed of several striking properties, and therefore could hardly fail to be detected if it were ever produced by volcanic action.

* The reader will immediately be led to consider the effect itself as analogous to that noticed under the name of cavernous lava, in Sir G. Mackenzie's 'Description of Iceland.'

It is true that phosphoric acid exists in the cavities of certain volcanic rocks, as in those of Murcia in Spain, combined with lime and other earths, but I do not know that it has ever been detected in a free or uncombined state among the products of any active volcano.

Are we at liberty to suppose that some less inflammable gas, such as simple hydrogen, or its combinations with carbon and sulphur, might, during their rapid ascent through the water, retain a sufficiently exalted temperature to inflame spontaneously on coming in contact with the air? Or may we adopt the still bolder hypothesis of Von Buch, who imagines some of the metallic bases of the earths or alkalies to be ejected and to become kindled on coming into contact with water? The phænomenon at least is not an isolated one, for it has been observed in the Azores, near Iceland, and in other localities.

Since the eruption of 1730–36, the island of Lancerote enjoyed a state of tranquillity until the 29th of August 1824, when at the port of Rescif and its environs earthquakes occurred, which became more terrible at night. They increased in violence the next day, and on the 31st, at seven in the evening, a volcano broke out a league from the harbour of Rescif, and half a league from the mountain called Famia. It vomited from its crater terrible flames which lighted up the whole island, as likewise stones of an enormous size reddened by the fire, the latter in such large quantity, that in less than twenty-four hours they formed a mountain of considerable size. This eruption continued till ten in the morning of the 1st of September, when the volcano seemed to close, only leaving fissures, from whence escaped a thick smoke covering all the neighbourhood. On the 2nd there arose three great columns of smoke, each of a different colour, one perfectly white, the other black, the third, which was the farthest off, red.

This volcano, says the account, still burns over a space of half a league in length and a quarter in breadth, and the mountain newly formed appears to be inaccessible, and does not exhibit lavas in any direction.

On the 4th a large column of smoke rose from the volcano, and on the 22nd of September it became again active, and

poured forth a quantity of water so considerable as to form a large stream, which diminished on the 23rd, and on the 26th had nearly disappeared*.

If we believe Von Buch, the island of Madeira is formed after the same manner as the Canaries, consisting of beds which have been elevated above the level of the ocean by elastic fluids, but are destitute of any crater from whence smoke and lava have been ejected.

The account however which Mr. Bowdich, in his posthumous work†, gave of the physical structure of the island, was in some respects somewhat different. That it is composed of volcanic matter cannot indeed be doubted, for it appears by his account that the rocks of the island principally consist of tuff, scoriæ, or basalt. The former, he says, sometimes contains bands, as it were, of pumice, traversing it in the direction of the bed; it is sometimes yellowish and sometimes red; it alternates repeatedly with the scoriæ, which again are continuous with a very cellular variety of the basalt, forming a connected bed or current, the direction of which may be presumed to be indicated by that of the cells, which are oval and elongated all in the same direction.

Besides this form of basalt, a compact and columnar variety is also seen, which in many places appears to cap all the other strata, but in others is itself covered by a thin stratum, consisting of fragments of porous basalt, cemented by a yellow tufa. This conglomerate likewise insinuates itself into crevices between the other strata. Compact basalt however is not confined to the uppermost beds, for in the centre of the island it is found immediately incumbent on a limestone, which Mr. Bowdich considers to belong to the transition series, and which is the fundamental rock hitherto discovered, being 700 feet in thickness. As to the age of this formation, however, Mr. Bowdich appears to have been mistaken, for a more recent and accurate observer (to whose paper I shall refer immediately ‡) assures us that it is entirely tertiary.

* Bulletin des Sciences for May 1825, copied from the Constitutionnel for October 23, 1824.

† Account of Madeira and Porto Santo, London, 1825.

‡ Mr. Smith of Jordan Hill.

All these beds, even the limestone, are traversed by very numerous dykes of basalt, which appear to be always compact, and have a natural cleavage at right angles to their walls.

Mr. Bowdich describes a small conical hill situated on the high table-land in the centre of the island, which has on its summit a small elliptical cavity, about 200 feet in diameter and 54 feet in depth. No stream of lava however has flowed from it, nor has it any of the usual appearances of a crater. He also notices an elliptical funnel-shaped depression about eighty feet above the sea, between the fort and Praya Bay, which seems to answer to the description given by Von Buch of a crater of elevation. It presents every evidence, says Bowdich, of having been formed by a minor volcanic heave, which threw up vast blocks of the rock it rent from beneath the ocean to form a passage, but did not eject any lava or contents of its own.

The strata here are stated to be inclined, but it would have been more satisfactory if Mr. Bowdich had informed us whether they dip in all directions away from the crater, as we should expect to be the case.

Granting however these cavities to have been produced in the manner Von Buch represents, it is still impossible to reconcile his view of the general elevation of the island by volcanic agency to the statements given by this last traveller.

It is true that there exists in the interior of the island a vast fissure, 1634 feet deep, and 3700 feet above the sea, "where," says Bowdich, "the basaltic rocks that compose the mountains seem to have been blasted and shivered by the great convulsion which rent the foundation strata, so as to create at once this stupendous valley, enlarged and deepened by the action of torrents which have battered it for ages."

But besides that the strata are not said to have that disposition, which is necessary in all cases to establish the fact of their having been heaved up, the circumstance of their resting upon a horizontal bed of limestone 700 feet thick seems fatal to such an hypothesis. This, Mr. Bowdich remarks, would demonstrate that Madeira pre-existed as a mass of transition, or probably of primitive and transition rocks, which were covered and elevated by successive streams and ejections of basalt and tufa derived from some submarine volcano.

Mr. Smith, of Jordan Hill*, has since communicated a paper on the geology of this island, which accords better with the views of Bowdich than with those of Von Buch.

The igneous rocks composing the greater part of the island are lavas, sand, and ashes, with bombs, lapilli, pumice, volcanic scoriæ, tufas, and conglomerates; the lavas wholly basaltic, containing crystals of olivine, and though sometimes compact, yet even then alternating with scoriform products. The whole character of the volcanic formation is such as to imply a subaërial origin, and this is corroborated by the fact, that the materials are dispersed without regard to their respective weights, as would have happened if they had been ejected under water. There are also roots of plants in the beds of vegetable soil, covered over by layers of various volcanic products, standing upright in the ground, and thus showing that the land was already elevated above the waters.

The principal chain of mountains must at one time, Mr. Smith says, have been much higher, because their very summits consist of beds which are met with only at the base of active volcanic cones. There is consequently no great crater in the island, but there are the ruins of several truncated craters, and many small lateral cones.

The most extensive of the former is the Curral dos Freiras, an immense ravine about three miles in length, one in breadth, and 2000 feet in depth, open on its southern side, and composed of beds dipping outwardly on all sides.

Mr. Smith concludes that it cannot have been a crater of elevation, from the materials of which it consists being of subaërial formation; but this is a question of theory, which will be considered afterwards.

There are numerous lateral cones to the west of Funchal, much covered by a rich vegetation, and sometimes also concealed by streams of lava or tuffs erupted from the crater at Cape Giram, in one instance to the thickness of 1400 feet. Everything implies a vast energy in the volcanic operations, as well as a long continuance of the igneous action.

The island of Porto Santo, according to Mr. Bowdich, differs from that of Madeira, in the occurrence of tertiary

* Proceedings of the Geol. Soc. vol. iii. p. 357.

sandstone and limestone alternating with the volcanic strata*. The lowest visible deposit is a calcareous tufa of a greenish grey colour, which extends on the north-east parts of the island to the height of 1600 feet, and is ribbed throughout with vertical dykes of a reddish brown basalt.

In the middle of the island there is a depression in the tuff, and in this basin a bed of sandstone has been deposited, the lower part of which is hard and solid, of a reddish buff colour and slaty structure, with indurated veins effervescing pretty vigorously, and presenting small black spots, apparently ferruginous; the upper of a looser consistence, and containing Helices, Bulimi, Ampullariæ, and other shells belonging to a recent epoch.

This sandstone seems to be of more recent origin than the volcanic matter, for it is not traversed by any dykes. In the neighbouring islet of Basco, the calcareous tufa is covered with beds of limestone rising 100 feet above the level of the sea, alternating with a conglomerate, in which nodules of basalt and wacke are inserted in a ferruginous sandy earth of a brick and dull orange-red, traversed by veins of mammillated carbonate of lime. This limestone presented immense masses of Lamarck's Cateniporæ (*Tubipora catenulata*), and contained specimens of the Cardium, Mytilus, Venus, Voluta, Turritella, Conus, and other shells. These beds are traversed in the same manner with dykes.

The tuff of Porto Santo is sometimes covered with a compact basaltic rock approaching to phonolite, which forms the peaks in the north-eastern part of the island. It is distinguished by its vitreous colour, numerous crystals of glassy felspar and lamellar structure; immediately beneath it are the dykes which descend through the tufa to the sea. Mr. Bowdich observed in one of them a deposit of native alum, derived probably from the decomposition of sulphuret of iron, and another of a bright orange ochre, which also appeared to have proceeded from an altered condition of the basalt.

Mr. Smith of Jordan Hill differs from Mr. Bowdich in representing the whole of the volcanic matter in Porto Santo as superimposed upon the tertiary limestone, and not as alternating with it. The greatest elevation of the latter, at San Vicente, is no less than 2500 feet, but this must have taken

* See Bowdich's work.

place antecedently to the ejection of igneous rocks, and not during the period of their emission.

Of the Azores we have obtained a geological account from my friend and fellow-student Dr. Webster, of Boston, in the United States*.

The island of St. Michael, the largest of them, is described by him as entirely volcanic, and as containing a number of conical hills of trachyte, several of which have craters, and appear at some former period to have been the mouths of so many volcanos. The trachyte is completely covered by the ejections of pumice and obsidian that have proceeded from these sources, and it is seldom that we are able to discover it, except in the ravines or on the summit of the hills.

This rock however, so far as I can collect from Dr. Webster's description, does not constitute the fundamental stratum; it has rather been forced through strata of tuff and of basalt, which extend over the island, covered however in most places by the ejections of pumice and obsidian. Dr. Webster notices likewise a description of lava which he compares to the cavernous variety mentioned by Sir G. Mackenzie; it is swollen into large blisters and other irregularities, and contains several remarkable caves, from the roof of which hang stalactites, as they may be termed, of lava, assuming a variety of curious arborescent figures.

The island of St. Michael is famous for its hot springs, which are impregnated with sulphuretted hydrogen and carbonic acid gases, thus seeming to attest that the volcanic action is still going on. Of this however, evidences have, within the present century, been afforded of a far more direct and positive nature. In the year 1811 a phænomenon occurred, similar in kind to that which I have already described as having happened in the Grecian Archipelago. After a succession of earthquakes experienced more or less sensibly in all the neighbouring parts, a new island arose in the midst of the sea, of a conical form, and with a crater on its summit, from which flame and smoke continually issued. The island, when visited soon after its appearance by the crew of the frigate Sabrina, was about a mile in circumference, and two

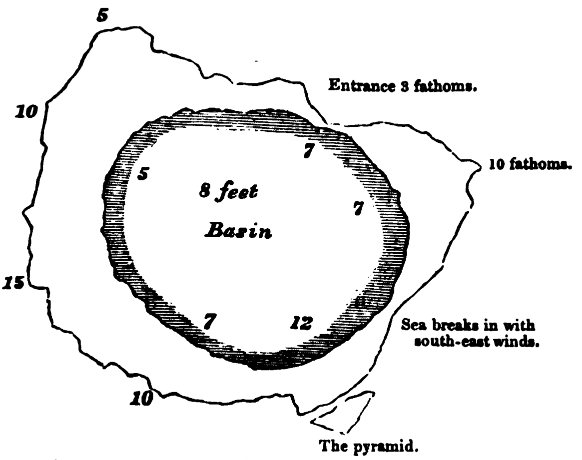
* Webster, 'Description of the Island of St. Michael,' &c. Boston, 1822.

or three hundred feet above the level of the ocean; it continued for some weeks, and then sunk again into the sea*.

A singular phænomenon occurs at a short distance from the coast near the town of Villa Franca, which has all the appearance of the crater of a volcano half-sunk below the level of the water. It consists of a circular basin, the interior of which contains water enough to float a small vessel, but the sides are elevated 400 feet above the sea. The basin is perfect except on one side, where the depth of water is sufficient to allow a ship to enter, and the latter would ride securely in the interior, were it not for a sinking of the basin on one side, which allows of the sea breaking over it when the wind sets in a south-easterly direction.

The sides of the basin consist of tuff, presenting an abrupt precipice externally, but dipping in a more gradual manner towards the interior, and Dr. Webster observes that the strata all slope in the latter direction and not towards the circumference, so that the structure is the very reverse of that described by Von Buch as belonging to the waters in the Canary Islands; and the circular cavity cannot in this case have been formed by an uplifting of the strata, but either by a subsidence of them, or, as Mr. Darwin conceives more probable, by the deposition of strata within a pre-existing cavity.

The following sketch may represent the appearance of the basin.



* Humboldt (Pers. Narr. vol. i. p. 243) remarks, that the formation of the island was anterior to that of the crater.

There also occurs in the midst of the sea a pyramidal mass of tuff only thirty or forty feet in diameter, consisting of horizontal strata from one to two feet in thickness. It is evidently the remnant of a formation, the greater part of which has been washed away, and seems to be analogous to that which I have noticed as occurring in the valley of the Puy en Velay in the south of France.

The other islands belonging to the same group appear to be similarly constituted. That of El Pico is the only one which contains a volcano at present in activity, for the great currents of lava which flowed in 1812 from the adjoining island of St. George, are considered as the results of a lateral eruption from this volcano. The summit of El Pico has been stated at no less than 9000 feet above the sea*; it consists of a conical mass of trachyte, and is constantly emitting smoke.

Mr. Darwin states that the central portions of the island of Terceira consist of trachyte, closely resembling that of Ascension. It is overlaid by streams of basaltic lava which may be traced to their respective craters. The only volcanic phænomenon now exhibited in this island is the emission of steam from a fissure in a trachytic rock, which undergoes in consequence those changes which I have pointed out as resulting from the action of aqueous vapour upon siliceous materials (see pages 244 and 311).

Notwithstanding the general volcanic character of the Azores, it is stated, on the authority of Count V. de Bedemar, that Flores and Graciosa consist of clay-slate, to which we must add the island of St. Marie, consisting of schistose rocks, which Von Buch conjectures to be of lias. The femur of a large animal is stated to project from the face of the rock in an inaccessible part of the cliff.

It may perhaps be inquired, as a subject associated with that of the volcanos now under our consideration, what degree of light geology is capable of affording with respect to the existence of a former continent or large island, serving to connect Europe with America, which the ancients sometimes allude to under the name of Atlantis.

It might appear at first sight, as if the knowledge we have of late

---

* Von Buch gives various estimates, varying from 6588 to 8586. He regards as the most probable that of Ferrer, which makes its height 7328 feet.

obtained with respect to the physical structure of these islands, which in such case would be regarded as the relics of this submerged country, lent some weight to the historical evidence in favour of its existence, since the volcanos that are proved to be in action in so many parts of the intermediate tract of ocean, might afford an adequate explanation of the *effect* supposed to have taken place.

But on the other hand, when we examine more narrowly into the appearances presented in the localities just described, we shall find it greatly more probable, that they have been separately raised from the bottom of the sea by volcanic agency, than that they have been severed apart, after having once constituted a single continuous tract of land. The details which I have extracted from Von Buch's interesting memoirs lead inevitably to this conclusion, as they tend to demonstrate, that the strata which form the basis of these islands, and through which the volcanic cones, where such exist, have been protruded, were formed originally at the bottom of the sea, and have been afterwards heaved up by elastic vapours acting from beneath.

It may be alleged indeed that the whole number of these islands does not consist of volcanic matter, for Gomera, Fortaventura, and others, contain rocks consisting either of primitive materials or of limestone; but the rare occurrence of the latter over a tract so vast, as that which the continent of Atlantis must be supposed to have occupied, certainly lends but little countenance to the hypothesis. It may be remarked too, that volcanos seem much more active in building up strata than in destroying them, and that if they had operated on so extensive a scale as must be assumed by those who attribute to their agency the destruction of a continent, they would on the other hand have raised up more extensive tracts of volcanic materials in the place of those they had been the means of subverting. It is sufficient indeed to cast a glance over the conjectural map of the Atlantis, by Bory St. Vincent*, to be convinced of the absurdity of any such hypothesis; for who can imagine a tract of land extending from 40° to 15° north latitude, having for its northern boundary the Azores, for its southern the Cape de Verde Islands, and for its eastern promontory the Peak of Teneriffe, to have been swallowed up in the ocean by causes in operation, within the period that has elapsed since the creation of man?

Nevertheless it is curious to remark, how often the early traditions which have been handed down to us from a remote age shadow out obscurely those physical truths which modern investigations reveal to us. Though the subsidence of a continent occupying any large extent

* See Bory St. Vincent sur les Iles Fortunées.

of what is now a part of the Atlantic could not, as would appear, have obtained currency among the Greeks from any remote records, yet the recent investigations of Professor E. Forbes, which have already been briefly adverted to (page 301), seem to point out the probability, that at a period, geologically speaking, not so very remote, such an event must have taken place, since they refer to an æra, at which species of plants and animals now existing on the surface of the globe were already in being, as having witnessed the union of the coasts of Spain with those of Ireland, by the interposition of a continent extending probably as far as the Azores. Thus we find the boldest fictions of the ancients rivalled by the speculations of the moderns, with this difference however, that what with the former was the mere creation of a prolific fancy, is in the latter arrived at by a slow and patient process of induction, just as the *dragons* of romance are realized in the *pterodactyls* of geology.

At a still lower latitude, though indeed not very remote from that part of the African coast in which some indications of igneous agency appear to present themselves, is the group of the Cape de Verde Islands.

They are said to consist principally of volcanic matter, but the only members of the group that have been described by any recent writer are Fuego and St. Jago.

The former appears to contain the only active volcano in the whole series. Small as the island is, it is said to rise to the height of 7000 feet above the sea. The cone, according to M. Duvalle*, is placed in the centre of a basaltic crater, being encircled, like that of Vesuvius, by a semicircular crest of rocks on one side, whilst on the other it is destroyed. Numerous cones of scoriæ are scattered over its flanks, the most recent dating from the years 1785 and 1799.

The crater of elevation, which surrounds the cone of eruption, is composed of basalt alternating with beds of conglomerate, and traversed by numerous veins. The cone itself rises from the bottom of the crater to the height of more than 3000 feet, and the culminating point of the circus is not far inferior in height to the peak itself.

With regard to the geological structure of St. Jago, Mr. Darwin has communicated several interesting facts†. It ap-

* Bulletin de la Soc. Géol. de France, vol. iii. 1846.

† Volcanic Islands.

pears that a stratum of white limestone, resting on ancient volcanic rocks, which, from the abundance of Patellæ and other littoral shells it contains, as well as from its mineralogical characters, would seem to have been deposited only in shallow water, is covered by a stream of basaltic lava, which is cellular both at bottom and at top, but in the centre compact. This calcareous rock is not, as might have been expected from the absence of any great pressure, deprived of its carbonic acid, but near the junction is curiously metamorphosed, either into a hard, compact, white, fine-grained rock, striped with a few parallel lines of black volcanic particles, or into a hard rock without any crystalline structure, thickly mottled with rounded spots of a soft ochreous substance. It is observable that no part of this limestone is converted into dolomite.

The lava also contains much carbonate of lime of a white powdery character in cells. The cells are likewise lined, and partly filled with a white, delicate network of carbonate of lime possessing a fibrous structure, as if it had been drawn out into threads whilst in a state of semi-fusion. The interior of the island is composed of volcanic rocks of older formation than those described, many of which resemble trachyte. No eruptions of recent date appear to have taken place in this island, which is chiefly interesting as exhibiting the effects of volcanic heat upon rocks of neptunian origin under an inconsiderable pressure. Knowing as we do that limestone retains its carbonic acid even at a very high temperature in an atmosphere of carbonic acid, we need not be so much astonished at the association of crystalline limestones with cellular lavas, or at the fusion of a calcareous breccia taking place in comparatively shallow water without the loss of its carbonic acid.

Below the Equator, in latitude 8°, and at a great distance from either continent, is the island of Ascension, which is entirely made up of volcanic matter. The central and more elevated parts of the island, according to Darwin*, consist of trachyte, with which are associated obsidian, hornstone, and several kinds of laminated felspathic rocks. The greater number of the hills however are composed of a white, friable

* Volcanic Islands.

stone, like a trachytic tuff, which I conceive to be analogous to that of M. Epomeo in Ischia, which I have called, hesitatingly, a pumiceous conglomerate. Mr. Darwin alleges in contradiction to this the presence of veins intersecting, and of crystals of felspar dispersed through the rock, but neither of these facts appears inconsistent with the idea of its having resulted from a re-aggregation of the component parts. Ejected masses of unchanged granite are imbedded in the midst of masses of scoriæ, as I have stated to be the case at Mount Etna.

The only exception to the volcanic character of the island consists in an accumulation of shells and corals along the sea-beach, agglutinated into a compact mass by the infiltration of calcareous matter. The rest would appear, from Mr. Darwin's description, to be of trachytic origin, and the curious transitions from this material into obsidian, which are dwelt upon by this geologist, will be noticed in a subsequent part of this work, wherein the differences between submarine and subaërial lavas come under our consideration.

Whilst Ascension seems to be of subaërial, St. Helena would appear to be, in great measure at least, of submarine formation. The first is composed of lava-streams, which, although they have not been erupted at any period since the island was first discovered, that is, within 350 years, are as glossy as if just poured forth. The craters from which they have proceeded are well-defined, and there is an entire absence of dykes.

In St. Helena, on the contrary, the course of no one stream of lava can be traced either by the state of its boundaries or of its superficies; the mere wreck of one great crater is left, and dykes are scattered in profusion throughout the whole substance of the basaltic masses which compose the island.

As at St. Jago and the Mauritius, the basaltic strata form a ring or circular rampart, open indeed to the south, and breached elsewhere by several other wide spaces, but surrounding the rest of the island, and rising to a somewhat higher elevation.

Within this outer circle is a central curved ridge of grey felspathic lavas and of tuffs, which seems like the last remnant

of the original crater that once existed in the centre of the island. It is almost precipitous within, but slopes more gently towards the circumference of the island, resembling the crater of Teneriffe in the relation it bears to the ring of basaltic rocks which encircles it.

Mr. Darwin, without entirely adopting the views of Von Buch with regard to the formation of these craters, admits generally, that they are formed by elevation, and that the whole island has been upheaved in mass, and not formed by successive ejections of lava.

It may be remarked, that both the felspathic and basaltic portions are equally reticulated with numerous dykes, which imply a stretching and a consequent elevation or displacement of the containing rock. These are generally coated by a thin glossy layer, which fuses into a black enamel, and is evidently analogous to the glossy superficial coating of many lava-streams.

Mr. Darwin seems to consider the circumstance of felspathic lavas or trachytes being more recent than those containing augite as rather anomalous, but it must be recollected, that the augitic lavas which he describes belong to the class of submarine lavas, and nothing is more common in the history of volcanic mountains than a trachytic cone encircled by an amphitheatre of basaltic rocks. The only circumstance therefore which forms in any degree an exception to the common rule, is, that the lavas ejected from the central cone should be all felspathic, but of this there are instances at the Solfatara in the lava of Mount Olibano, and elsewhere. May not these lava-streams be of subaërial formation, although the basaltic rocks encircling them were poured forth under water?

It would appear* that at various times during the last century, in a space of open sea between long. 20° and 22° west, and about half a degree south of the Equator, a series of volcanic phænomena have been observed, consisting of earthquakes, floating scoriæ, and columns of smoke, seeming to show that an island or archipelago is in process of formation in the middle of the Atlantic; a line joining St. Helena and Ascen-

* Nautical Magazine, 1835, and Comptes Rendus, 1838, quoted by Darwin, Volcanic Islands, p. 92.

sion, prolonged, intersects this slowly nascent focus of volcanic action.

Nearer the coast of America, in lat. 3°·50, are several islets called Fernando Noronha, which Mr. Darwin has briefly noticed. They consist of various kinds of lava; but the most remarkable feature is a hill 1000 feet high, of which the upper 400 feet consist of a precipitous pinnacle of columnar clinkstone with numerous crystals of felspar and a few needles of hornblende.

The islands of Tristan d'Acunha exist in the South Atlantic Ocean, about 1500 miles from any land, in W. long. 11°·44, S. lat. 37°·6, and the largest of the group consists of a single mountain, certainly not less than 7000 feet high, though some estimate it at 9000 feet, composed of a truncated cone, from the centre of which rises a dome 5000 feet in height*.

The cone consists of a number of alternating strata of tufa and augitic lava intersected by numerous dykes. The dome is difficult of ascent, from its extreme steepness, and from the loose incoherent nature of the rocks. For a considerable way the surface is covered with extensive patches of fern, grass, or shrubs, the ground being swampy; but for a distance of a mile and a half from the summit it is perfectly bare, consisting of loose scoriæ and fragments of cellular lava. Ridges of lava, which descend from the summit, afford the only means of climbing to the crater.

The latter is nearly a mile in circumference, and has a small lake of pure water at its bottom. Some isolated cones, entirely bare, are scattered over the island in various spots.

* Linnæan Transactions, vol. xii.

CHAPTER XXIX.

WEST INDIAN ARCHIPELAGO.

Division of the Islands into four classes:—1st class—Trinidad, its pitch-lake—Jamaica, extinct volcano—Cuba, upraised beach—St. Domingo—Porto Rico.—2nd class—Grenada—St. Vincent—St. Lucia—Martinique—Dominica—Guadeloupe—Montserrat—Nevis—St. Christopher's—St. Eustachia.—3rd class.—4th class—Antigua.

The islands constituting the West Indian Archipelago are commonly distinguished, according to their size, into the Greater and Lesser Antilles, but they have been divided by a French geologist*, with more reference to their physical constitution, into four classes.

The first of these includes such as consist, partly of primitive (or to speak more correctly, of the more ancient) rock-formations, and partly of those derived from volcanos.

The second, those which are wholly volcanic.

The third, those entirely calcareous.

The fourth, such as are partly of volcanic origin, and partly composed of limestone with organic remains.

This classification cannot be regarded as precisely correct, for we do not know that all those of the first class contain volcanic products, nor are those of the second entirely composed of them—nevertheless for convenience sake it may be adopted, seeming, as it does, to place together those islands which are analogous, although not altogether identical, in structure.

Now to the first of these classes are referred all the islands of the largest size, such as Trinidad, Jamaica†, Cuba, St. Domingo, and Porto Rico.

* See Cortes, Journal de Physique, tom. lxx.

† Jamaica, strictly speaking, does not belong to this class, since it appears from Sir H. De la Beche's account, that besides transition rocks and some of the older secondary, it contains likewise an extensive formation of white limestone, referable to the tertiary period.—See his paper in the Geol. Trans. vol. ii. 2nd series.

With regard to Trinidad however it may be observed, that it seems rather to make a part of the continent, than to be a member of the system of mountains traversing the other West India Islands.

Dr. Nugent observes, that its rocks are either decidedly of primitive or of alluvial origin*. The great northern range of mountains that runs from east to west, and is connected with the high land of Paria on the continent by the islands of the Bocas, consists of gneiss; of mica-slate, containing great masses of quartz, and in many places approaching so near to the nature of talc, as to render the soil quite unctuous by its decomposition; and of compact bluish limestone, with frequent veins of white crystallized carbonate of lime. From the foot of these mountains for many leagues to the northward, there extends a low and perfectly level tract of land, evidently formed by the detritus of the mountains, and by the copious tribute from the waters of the Ohio, deposited there by the influence of currents.

The celebrated pitch-lake exists in the midst of a clayey soil; it is a vast expanse of asphaltum, perhaps three miles in circumference, which in the wet season is sufficiently solid to bear any weight, but in hot weather is often in a state approaching to fluidity. The manner in which it was originally formed may perhaps admit of an explanation, by considering certain analogous phænomena that present themselves in its vicinity. Thus on the eastern coast there is a pit which throws up asphaltum, together, as it is said, with violent explosions, smoke and flames. Almost in the same parallel, and also in the sea, but to the west of the island (near Punta de la Brea, south of the port of Naparima), is a similar vent. At the south-west extremity of the island, between Point Icacos and the Rio Erin, are small cones, which appear to have some analogy with the volcanos of air and mud which occur at Turbaco in New Grenada, and are described by Humboldt.

It is possible that the whole of these phænomena may be analogous to those of Macaluba and of the Lago Naftia in Sicily, which, though they occur most frequently in the vicinity of rocks derived from volcanic operations, are to be viewed per-

* Geol. Transactions, vol. i.

haps rather amongst the *secondary* than the *primary* effects of this deep-seated cause.

Mr. Jukes informs me, that he found in Trinidad a rock like a white granite, probably the same as that described by Dr. Darwin in Ascension, imbedded in black lava, and also beds of sandstone comprising recent shells, amongst which were *Neritæ* still retaining their colour.

We are indebted to Sir Henry De la Beche for a sketch of the geology of the island of Jamaica*, from which it appears, that whilst trap rocks are pretty widely distributed, subaërial volcanos have not been discovered, except in one locality.

The following is the description given by Sir Henry of the place in question:—

"In that part of Jamaica which I examined, I observed rocks of a volcanic character only at the Black Hill, which is situated between Lennox, Low Layton, and the sea; this hill, when viewed from the neighbourhood of Buff Bay, has a somewhat conical appearance, and rises above the low hills that extend towards Savanna Point; the hill however, when approached, is seen to be no cone, notwithstanding its effect at a distance.

"The rock, of which the Black Hill is composed, is greyish green and hard, gives out an earthy smell when breathed upon, and may be described in general terms as a volcanic amygdaloid, the cells, with which it abounds, being mostly filled; those however which have been exposed to the weather are frequently empty, as are also those within a few inches from the surface. The interior of the empty cells is often incrusted with a little oxide of iron, while those that are full, and which convert the rock into an amygdaloid, contain chalcedony, calc-spar, &c."

Of the physical structure of Cuba we know at present but little, for although Humboldt twice visited the Havana, he does not appear to have extended his excursions far into the interior, and the whole of his information on this subject is comprised within a very short compass†.

* Geol. Transactions, vol. ii. New series.

† Essai Politique sur l'Ile de Cuba, p. 45, *et seq.*

He says that four-fifths of the surface of the island is low, not more than from forty-five to sixty toises above the sea, and that it consists of secondary and tertiary formations, pierced in some places by rocks of granite-gneiss, syenite and euphotide. The most elevated group of mountains is found on the south-east extremity of the island between Cabo-Cruz, Punta Maysi and Holguin. It is called the Sierra del Cobre, and rises to a height of more than 1200 toises.

Humboldt speaks of calcareous rocks found near Matanzas which belong to the Jura formation, but during the cursory visit which I paid to that locality in 1838, I only observed an extensive coralline limestone of recent date, upheaved from the sea. It contains large caverns, and is filled with a profusion of very beautiful corals, as well as of shells belonging to species now existing. It forms a kind of belt along the northern coast, not only between Havana and Matanzas, but I believe for a much greater distance, and is probably one of the most extensive coral beaches to be found in any part of the world.

East of the Havana, rocks of serpentine and syenite make their appearance. I observed the former at Guanamacoa, south of the city; but no volcanic rocks, such as trachytes, dolerites or basalts, have yet been observed, although earthquakes are not uncommon, especially in the eastern portion of the island.

The latter borders upon that district in St. Domingo which is most exposed to these catastrophes; for some of the worst earthquakes in that island have been felt between Cape Tiburon and Port au Prince, extending to Porto Rico on the one hand and to Jamaica on the other. In that of 1770 the whole of this granitic neck of land was laid waste by the ravages they occasioned.

Concerning the geology of St. Domingo I have been unable to obtain any information; and with respect to Porto Rico, we are only told by Cortes, in his Memoir on the Antilles before referred to, that it contains ancient volcanic as well as primitive or plutonic rocks.

The second class of islands, which consist exclusively of volcanic rocks, occurs together in one line, extending nearly

north and south, and terminating in Trinidad, being circumscribed within north lat. 12° and 18°, and west long. 61° and 63°. Whatever indications of this kind present themselves further to the west belong to eruptions of an older date.

The following is a summary of them, beginning with the most southern member of the range :—

1. Grenada. The mountain called Le Morne Rouge is an extinct crater, consisting of scoriæ and vitrified matter. Columnar basalt crowns two of the heights, and there are boiling springs.

2. St. Vincent contains an active volcano, called Le Souffrier, or Morne Garou, the loftiest mountain in the chain which runs through the island, being 4740 feet above the sea. It first threw out lavas in 1718, but its most tremendous eruption was in 1812, when there issued from the mountain a dreadful torrent of lava, and such clouds of ashes as nearly overspread the island, and injured the soil in a manner from which it has not even yet recovered. The total ruin of the city of Caraccas preceded this explosion by thirty-five days, and violent oscillations of the ground were felt both in the islands and on the coasts of Terra Firma*.

3. St. Lucia contains a very active solfatara, from 1200 to 1400 feet in height. Besides a considerable condensation of sulphur given out from the crevices, there is likewise an emission of jets of hot water, which fill periodically certain small basins, like the Geysers of Iceland.

Von Buch† states, on the authority of a writer in the Swedish Transactions, that a small eruption of stones and cinders took place from its crater in 1766‡.

* Humboldt's Pers. Narr. vol. iv. p. 26.

† Canary Islands.

‡ These ashes were conveyed to Barbados in spite of the east wind which was blowing at the time, although the latter island lies to the eastward of St. Vincent's. This curious fact proves the existence of an upper current in the atmosphere, flowing in a contrary direction to that near the surface, thus establishing the conjecture of Halley with regard to the trade-

4. Martinique, strictly speaking, can hardly be said to belong to this class, for limestone is here seen resting upon the volcanic products.

The latter however constitute the fundamental rock throughout the whole island, and form its three principal hills, which are called Vauclin, the Paps of Carbet, consisting of felspathic lava, the summits of which are the most elevated points in the whole of this series of islands, and Montagne Pelée. In the neighbourhood of the latter pumice is abundant, which may make us presume the existence of trachyte. Between the first and second of these mountains is found on a neck of land a tract composed of ancient basalts, called La Roche Carrée. Hot springs occur at Prêcheur and Lameutin.

5. Dominica is completely composed of volcanic matter. There are several solfataras, but no active vent. Trachyte is found at the base of the mountains, which rise to the height of 5700 feet.

6. Guadeloupe may be divided into two parts, according to its physical structure.

The first, properly called Guadeloupe, consists entirely of volcanic rocks, and therefore belongs to this division of our subject; the second, named Grande Terre, consists of a limestone with shells identical with those now found in the neighbouring seas, covered by a bed of clay, and containing rolled masses of lava. The volcanic part of the island contains fourteen ancient craters, and one in a state of present activity. The eruption of 1797 took place from an elevation of 4800 feet. Pumice, ashes, and clouds of sulphureous vapours were then ejected. The particulars are given in the report made to the French Government on the state of the volcano in 1797 by M. Amie.

On the 3rd of December 1836*, an enormous quantity of

winds. A similar opposition of currents is observed in the Canary Islands, for on the summit of the Peak of Teneriffe a violent west wind prevails at the very time when the trade-winds are blowing in an easterly direction below.—See Halley, Phil. Trans. vol. xvi. p. 151. Humboldt's Pers. Narr. vol. i. p. 132. Von Buch on the Climate of the Canary Islands, in the Transactions of the Berlin Academy, and Ed. Phil. Journal, July 1826.

* Comptes Rendus, 1837, pp. 294 and 652.

ashes were ejected from the eastern crater, whilst mephitic vapours were exhaled from other parts of the volcano; and this was followed, on the 12th of February 1837, by the emission of an enormous quantity of mud from a fissure on the north-western flank of the mountain, sufficient to swell the rivers that flowed down the slope in the same direction, and to raise their level as much as twenty feet. The eruption was attended by earthquake-shocks experienced all over the island. M. Elie de Beaumont has pointed out the differences that exist in the composition of the ashes thrown out from this volcano, and from Mount Etna. The former are of a dark grey colour, composed of two different constituents, one of which is attacked by acids, the other not. The portion dissolved seems to consist of labradorite, and constitutes about 32 per cent. of the whole. The undissolved part occurs in white milky grains, and consists of ryacolite or of glassy felspar. There seems to be but little difference between the nature of the sand or ashes ejected in the former eruption of 1797 and in that of 1836, or in that of the sand and mud emitted on the last occasion.

The ashes, on the contrary, thrown out by Mount Etna, whether in 1818, 1822 or 1832, although presenting certain minor differences in their characters, seem nevertheless equally to consist mainly of labradorite and of oxidulous iron.

7. Montserrat—a solfatara, emitting abundant vapours of sulphuretted hydrogen from fissures in all parts of the mountain. The latter, judging from Dr. Nugent's description*, would consist of trachyte, made up of fine porphyritic lavas, with large crystals of felspar and hornblende, near the estate called *Galloway's*, often much decomposed by the sulphureous exhalations.

8. Nevis contains crystalline rocks apparently abounding in felspar, and much clay probably resulting from its decomposition.

It possesses a solfatara and several thermal springs, two of which are noticed by Dr. John Davy as being in repute for

* Geological Transactions, vol. i.

their medicinal virtues. The temperature of the water in them, just where it issues from the earth, is 110°·5 Fahr.

A considerable part of its solid constituents is silica, which Dr. Davy conceives to be, in this instance, held in solution by carbonic acid*.

9. St. Christopher's. The most elevated mountain in the island, Mount Misery, consists of trachyte, and possesses a perfect crater, exhaling sulphur. There was a great eruption from it in 1692.

10. St. Eustachia contains the most perfectly preserved crater in the Antilles, called from its form the *Punchbowl*. It is surrounded by pumice.

The 3rd class comprehends the islands of Margarita, Desirade, Curaçao, Bonaire, and in general all the islands of low elevation; they consist entirely of coralline limestone of very recent formation.

The 4th class, partly composed of volcanic products and partly of shelly limestone, comprises the islands of Antigua, St. Bartholomew, St. Martin and St. Thomas.

Antigua is stated by Dr. Nugent† to be composed, on the north and east, of a very recent calcareous formation, corresponding with that of Guadeloupe, in which an admixture of marine and freshwater shells is found; subordinate to which rock on its southern limit, we find extensive masses of coarse chert, full of casts of shells, chiefly Cerithia. It is sometimes intermixed with marl.

Beneath these beds occurs an extensive series of stratified rocks, which Dr. Nugent has chosen to call claystone conglomerate, but which seem from his description to be a sort of trachytic breccia.

The rock has generally an argillaceous basis, with minute crystals of felspar imbedded, and possesses a remarkably green tinge from the numerous spots of green earth intermixed.

Its brecciated character is derived from the fragments of

* See Dr. John Davy in the Ed. Phil. Journ. for July 1847.

† Geol. Transactions, vol. i. new series.

silicified wood, chert, agate, jasper, porphyry, lava, and other substances imbedded. The silicified woods are particularly abundant.

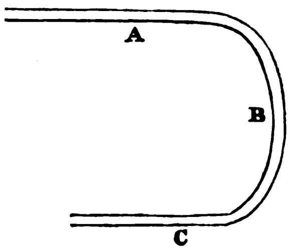
Respecting the remaining islands, I possess no information that can be relied on, and it is much to be wished that some geologist, in imitation of what has been done by Humboldt on the American continent, and by Von Buch in the Canaries, would present us with a detailed account of the physical structure of the Antilles collectively considered.

The whole of the volcanic operations above-described appear to have taken place, geologically speaking, at a very recent epoch, for the calcareous beds with which these rocks are associated all belong to a period when the shells of the present ocean were already in existence.

Hence if, as Cortes observes, we figure to ourselves the condition of the Minor Antilles before the elevation of the coral rocks of which it principally consists, we shall find the whole Archipelago disappear, excepting a few primary rocks occasionally scattered about.

The volcanic islands are all placed in one series, forming an arc, connecting, by means of its two extremities, the primary mountain range of Porto Rico, St. Domingo, and Jamaica with the parallel chain of the Silla in the Caraccas, and the connexion between the latter and the volcanos of the Antilles was fully established in 1812, by the cessation of the earthquakes on the mainland so soon as the crater of St. Vincent showed symptoms of activity.

Thus if the parallel lines A stand for the primary range of the Larger Antilles; and those marked C for the chain of the Caraccas; B will denote the position of the volcanic islands connecting both.



CHAPTER XXX.

VOLCANOS OF NORTH AMERICA, OR ABOVE THE ISTHMUS OF DARIEN.

North and Central America—Oregon Territory—California—Mexico—Guatemala.

No signs of volcanic action have been discovered in any part of the continent of North America above the tropic of Cancer, excepting to the west of that great dividing ridge, called the Rocky Mountains, which stretches in a direction north-west and south-east, from the Arctic Sea to the Isthmus of Panama.

This lofty system consists, so far as it has been yet examined, entirely of primary formations; but to the west, and nearly parallel to it, is a distinct group, called the Far West or Sierra Nevada range, which rises to a greater height even than the Rocky Mountains themselves; the pass which was crossed by Fremont* in one of his exploring expeditions, in lat. 38°·44, long. 120°·28, being no less than 9338 feet above the sea.

This latter chain runs very near to the coast with which it is parallel; and as the waters that accumulate in the great longitudinal valley intervening between it and the Rocky Mountains, can only find an outlet to the sea in the few spots where a gap occurs in the ridge, as for instance where the Columbia River flows into the Pacific, we can readily understand the paucity of large streams, as well as the existence of extensive lakes, some of which, as that of Utah, by reason of having no outlet, are salt or brackish.

Now volcanic phænomena appear to occur abundantly in many parts of this chain, as well as in the valley to the east of it.

Beginning as far north as latitude 60°, we find the Mount

* Fremont, Two Exploring Expeditions, 1846.

St. Elias, probably the loftiest eminence in the northern continent of America, being nearly 18,000 feet above the sea, which is stated to be an active volcano, and is perhaps connected with the chain of the Aleutian Islands already alluded to.

Mount Fairweather, Cerro de Buen Tiempo, a little to the south, is another volcano about 15,000 feet in height; and to the north, volcanic appearances have been found on the coasts of Prince William's Sound.

Another volcano, in lat. 57°·3, has been recognized by Captain Lisiansky; it is called Mount Edgecumbe, and consists of basaltic porphyry with crystals of felspar, whilst its flanks are covered with pitchstone and pumice. According to Ernest Hoffman its height is 2853 feet.

In lower latitudes the volcanic action seems either extinct or more languid. Near the Utah lake, in the 40th parallel, are the Beer Springs, thermal waters strongly impregnated with carbonic acid gas, and hence possessing the pungent taste from which their name is derived. The hottest, called Steamboat Spring, has a temperature of 85°. Scoriform basalt occurs in its vicinity, and not far from it is a perfect volcanic crater, 360 paces in circumference and sixty feet in depth, with every indication of recent fusion in the rocks of which it is composed.

Other thermal waters occur, associated with vesicular trap, in lat. 42°·55, and cause a copious deposition of calcareous matter. Indeed, within the valley intervening between the two parallel chains of mountains, volcanic rocks and thermal springs abound between the 38th and 42nd parallel of latitude; and in one of the chain of lakes already noticed as existing in this valley, there rises a pyramidal mass of rock, probably volcanic, which has caused it to be distinguished by the name of the Pyramid Lake.

In the peninsula of Old California there is a chain of mountains forming the central ridge, and called Cerro de la Giganta (from 4592 to 4920 feet), which appears to be of volcanic origin; and one of them, the Monte de las Virgines, is said to be in a state of activity. It is to be regretted that we know as yet so little of the geology of this part of the continent.

In Mexico, the most northern point in which any signs of volcanic action are known to occur is near the town of Durango, in lat. 24°, long. 104°, where a group of rocks covered with scoriæ, and consisting of basaltic amygdaloid, called La Breña, rises in the midst of a level plain.

On the summit of one of the neighbouring mountains a regular crater was discovered, but no active volcanos are to be met with until we reach the parallel of the city of Mexico itself, where almost in the same line occur five, so placed that they appear to be derived from a fissure traversing Mexico from west to east, in a direction perpendicular to that of the great mountain chain, which, extending from north-west to south-east, constitutes the great table-land of the American continent. It is interesting to remark, that if the same parallel line which connects the active volcanos of Mexico be prolonged in a westerly direction, it would traverse the group of islands called the Isles of Revillagigedo, which there may be reason to consider volcanic from the pumice found amongst them*.

The most eastern of the above volcanos, that of Tuxtla, is situated a few miles to the north-west of Vera Cruz. It had a considerable eruption in 1793, the ashes from which were carried as far as Perote, a distance of fifty-seven leagues.

In the same province, but farther to the west, occur, the volcano of Orizaba, the height of which is 17,300 feet, and the Peak of Popocatepetl, 300 feet higher, the loftiest eminence in New Spain. The latter is continually burning †, though for several centuries it has thrown nothing up from the crater but smoke and ashes.

To the west of the city of Mexico are the volcanos of Jorullo and Colima. The elevation of the latter is estimated at about 9000 feet. It frequently throws up smoke and ashes, but has not been known to eject lava.

The volcano of Jorullo, situated between Colima and the town of Mexico, is of much more modern date than the rest, and the great catastrophe which attended its first appear-

* See the map of Mexico which accompanies this volume.

† Mr. Bullock has called in question this statement of Humboldt's; but a still more recent traveller, Mr. Stapleton, has confirmed it (Bull. des Sci. for September 1825).

ance is perhaps (says Humboldt) one of the most extraordinary physical revolutions in the annals of the history of our planet*.

Geology, he remarks, points out parts of the ocean near the Azores, in the Egean Sea, and to the south of Iceland, where, at recent epochs, within the last 2000 years, small volcanic islands have risen above the surface of the water; but it gives us no example of the formation, from the centre of a thousand burning cones, of a mountain of scoriæ and ashes 1695 feet in height, comparing it only with the level of the adjoining plains, in the interior of a continent, thirty-six leagues distant from the coast, and more than forty-two leagues from every other active volcano.

A vast plain extends from the hills of Aguasarco nearly to the villages of Teipa and Pelatlan, both equally celebrated for their fine plantations of cotton. Between the Picachos del Mortero, the Cerros de las Cuevas and de Cuiche, this plain is only from 2400 to 2600 feet above the level of the sea. In the middle of a tract of ground in which porphyry with a greenstone base predominates, basaltic cones appear, the summits of which are crowned with vegetation, and form a singular contrast with the aridity of the plain, which has been laid waste by volcanos.

Till the middle of the last century, fields covered with sugar-cane and indigo occupied the extent of ground between the two brooks called Cuitimba and San Pedro. They were bounded by basaltic mountains, the structure of which seems to indicate that all this country, at a very remote period, had been already several times convulsed by volcanos. These fields, watered by artificial means, belonged to the farm of Don Pedro di Jorullo, and were among the most fertile in the country.

In the month of June 1759 a subterraneous noise was heard. Hollow sounds of the most alarming nature were heard, accompanied by frequent earthquakes, which succeeded each other for from fifty to sixty days, to the great consternation of the inhabitants of the farm. From the beginning of September everything seemed to announce the complete re-establishment of tranquillity, when in the night of the 28th and 29th the horrible subterraneous noise recommenced. The affrighted Indians fled to the mountains of Aguasarco. *A tract of ground from three to four square miles in extent rose up in the shape of a bladder.* The bounds of this convulsion are still distinguishable from the fractured strata.

* Nouvelle Espagne, p. 248, fol. ed.

The annexed woodcut will convey some idea of the effect produced.

The Malpays near its edges is only thirty-nine feet above the old level of the plain, called *Las Playas de Jorullo*; but the convexity of the ground thus thrown up increases progressively towards the centre to an elevation of 524 feet.

VOLCANO OF JORULLO.

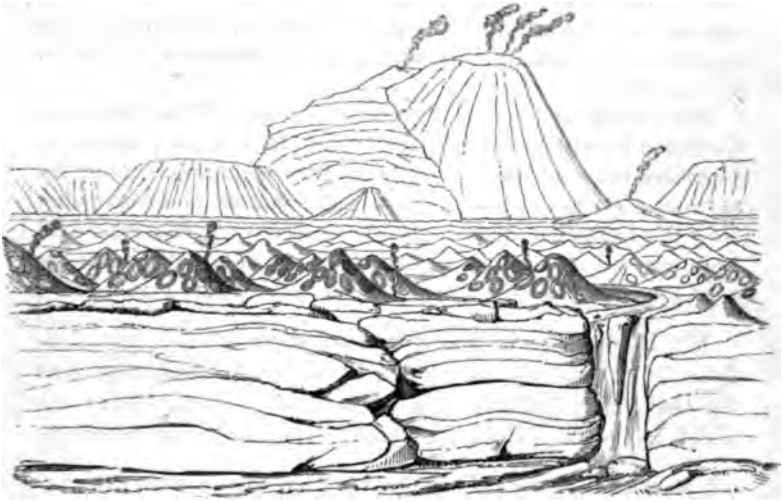
Section of Jorullo and the Malpays.

Those who witnessed this great catastrophe from the top of Aguasarco assert, that flames were seen to issue forth for an extent of more than half a square league, that fragments of burning rocks were thrown to prodigious heights, and that through a thick cloud of ashes, illumined by volcanic fire, the softened surface of the earth was seen to swell up like an agitated sea. The rivers of Cuitimba and San Pedro precipitated themselves into the burning chasms. The decomposition of the water contributed to invigorate the flames, which were distinguishable at the city of Pascuaro, though situated on a very extensive table-land 4592 feet above the plains of Las Playas de Jorullo. Eruptions of mud, and especially of strata of clay, enveloping balls of decomposed basalt in concentrical layers, appear to indicate that subterraneous water had no small share in producing this extraordinary revolution. Thousands of small cones, from six to ten feet in height, called by the natives *ovens* (Hornitos), issued forth from the Malpays. Although, according to the testimony of the Indians, the heat of these volcanic ovens has suffered a great diminution during the last fifteen years, I have seen the thermometer rise to 212° on being plunged into fissures which exhale an aqueous vapour. Each small cone is

a *fumarole*, from which a thick vapour ascends to the height of from twenty-two to thirty-two feet. In many of them a subterraneous noise is heard, which appears to announce the proximity of a fluid in ebullition.

In the midst of the ovens six large masses, elevated from 300 to 1600 feet each above the old level of the plains, sprung up from a chasm, of which the direction is from N.N.E. to S.S.W. This is the phænomenon of the Monte Nuovo of Naples, several times repeated in a range of volcanic hills. The most elevated of these enormous masses, which remind us of the Puys in Auvergne, is the great volcano of Jorullo. It is continually burning, and has thrown up from its north side an immense quantity of scorified and basaltic lavas, containing fragments of primitive rocks. These great eruptions of the central volcano continued till the month of February 1760. In the following years they became gradually less frequent.

The following woodcut is reduced from the engraving in Humboldt's 'Atlas Pittoresque,' intended to illustrate the general aspect of this remarkable locality.



The Indians, frightened at the horrible noises of the new volcano, abandoned at first all the villages situated within seven or eight leagues' distance of the *Playas de Jorullo*. They became gradually however accustomed to this terrific spectacle; and having returned to their cottages, they advanced towards the mountains of Aguasarco and Santa Inës, to admire the streams of fire discharged from an infinity of small volcanic apertures of various sizes. The roofs of

the houses at Queretaro, at a distance of more than forty-eight leagues in a straight line from the scene of the explosion, were at that time covered with ashes.

Although the subterraneous fire now appears far from violent, and the Malpays and the great volcano begin to be covered with vegetables, we nevertheless found the ambient air heated to such a degree by the action of the small ovens (*Hornitos*), that the thermometer at a great distance above the ground, and in the shade, rose as high as 109° of Fahrenheit. This fact proves that there is no exaggeration in the accounts of several Indians, who affirm that for many years after the first eruption, the plains of Jorullo, even at a great distance from the ground which had been thrown up, were uninhabitable, from the excessive heat which prevailed in them.

The traveller is still shown, near the Cerro de Santa Inĕs, the rivers of Cuitimba and San Pedro, the limpid waters of which formerly watered the sugar-cane plantations of Don Andre Pimentel. These streams disappeared in the night of the 29th of September 1759; but at a distance of 6500 feet farther west, in the tract which was the theatre of the convulsion, two rivers are now seen bursting through the argillaceous vault of the *Hornitos*, which make their appearance as warm springs, raising the thermometer to 126° of Fahrenheit.

The Indians continue to give them the names of San Pedro and Cuitimba, because in several parts of the Malpays great masses of water are heard to run in a direction from east to west, from the mountains of Santa Inĕs towards *l'Hacienda de la Presentacion*. Near this habitation there is a brook which disengages sulphuretted hydrogen. It is more than twenty-three feet in breadth, and is the most abundant hydro-sulphureous water which I have ever seen*.

Mr. Burkart†, who has visited Jorullo more recently, confirms in general the above statements; but informs us that the *Hornitos* or little cones, in the interval of twenty-four years which has elapsed since Humboldt's visit, have either entirely

* Mr. Poulett Scrope, Mr. Lyell, and others, have questioned the correctness of the representation which Humboldt has given of the above phænomena, but without, as I conceive, being able to substitute any more plausible hypothesis. Mr. Scrope's view of the nature of lava and trachyte is indeed too unchemical to require any detailed notice, and the objections of the other opponents will be best considered in a future chapter, when the general question of the elevation of volcanic mountains will come before us.

† Aufenthalt und Reisen in Mexico in 1825 und 1834. Stuttgardt, 1836.

disappeared, or have completely changed their form. Very few of them indicate a higher temperature than that of the surrounding atmosphere, and hardly any of them evolve vapour. Near the edge of the upheaved ground the small cones are chiefly composed of loose, and often porous basaltic lava, containing much olivine in grains, but more rarely conchoidal augite.

The five active volcanos just noticed appear to be connected by a chain of intermediate cones running in a parallel direction, and exhibiting evident indications of a similar origin.

Thus Orizaba is connected with Popocatepetl by the Coffre de Perote, and with Jorullo by the extinct volcano of Mexico, otherwise called Iztaccihuatl; and the geological structure of these and all the other lofty mountains that rise above the table-land of Mexico on the same parallel, appears to be the same, they being composed of trachyte, from apertures in which the existing volcanos act*.

Central America.

In the provinces of Guatemala and Nicaragua, belonging to the present republic of Central America, which lie betwixt Mexico and the Isthmus of Darien, the volcanos, instead of being placed nearly at right angles to the Cordilleras, run parallel to that chain.

There is perhaps no part of the world where so many active vents lie within a short compass, coupled also with so large a number, which, although extinct, seem to belong to the same period in the history of our planet.

Humboldt† enumerates thirty-five, either of one or the other kind, and Von Buch‡ considers as many as twenty-eight of these as belonging to the class of active vents.

They are all situated between latitudes 16° and 10°; the most northern being the volcano of Soconusco, situated north of the lake of Atitlan; the most southern that of Barua, near the Gulf of Dulce, considerably below the great lake of Nica-

* Humboldt, Gissement des Roches, 327.

† Volcanos of Guatemala, Phil. Magazine for 1827, translated from the 'Hertha.'

‡ Canary Islands.

ragua. They are all near the sea, and run in a line parallel with the coast. There is an interval of more than 600 miles between the most northern of these volcanos and that of Colima in Mexico, a granitic range of mountains in the province of Oaxaca intervening.

Next to the volcano of Soconusco is that of Amilpas, which smokes but seldom, and consists of two distinct peaks.

3. Sapotitlan.

4. Tajamulco or Quesaltenango.

5. Atitlan, south of the great lake of that name, the four preceding volcanos being north of it. A lofty mountain constantly emitting smoke.

6, 7. Toliman and Acatenanzo, not known however to be active vents, perhaps only peaks of trachyte.

8, 9, 10. The three volcanos near the city of Guatemala; two of them styled the Volcanos de Fuego, as they throw out smoke; the third, the Volcano de Agua, which only ejects water.

The two Volcanos de Fuego are distinguished by the names of the volcano of Pacaya, and the volcano of Guatemala. The volcano of Pacaya has had eruptions in 1565, 1651, 1664, 1668, 1671, 1677, and 1775, emitting pumice, sand and scoriæ, together with streams of lava. The volcano of Guatemala is in the shape of a beautiful cone, though somewhat disfigured by several hills of scoriæ, the remains of lateral eruptions. For the last century it has only emitted smoke and flame; but between 1581 and 1737 eight several eruptions of it are on record.

The Volcan di Agua (Water-Volcano) is of enormous height, being covered with eternal snow, in the latitude of 14°. Capt. Basil Hall estimates it at more than 14,000 feet, but a recent traveller states it at 12,600. It has the form of a blunted cone clothed with perpetual verdure to its summit. The crater is from forty to sixty yards in depth, and about 150 in diameter,—the sides and bottom strewed with masses of rock, apparently showing the effects of boiling water or of fire.

By a deluge of water from this volcano in 1527, the original city of Guatemala was overwhelmed; and the next built, called the Old City, *La Antigua*, was ruined by an earthquake in 1773. The present capital is situated at a distance of eight leagues from the mountain.

11. Isalco or Sonsonate, a mountain three leagues from the town of that name, frequently active. The most considerable eruptions occurred in 1798, and from 1805 to 1807. It gives out abundance of

ammonia, in what state of combination does not appear, probably as a muriate.

12. Apaneca, ten leagues from Sonsonate, perhaps extinct.

13. St. Salvador, near the town of that name, is also very active.

14. S. Vincent had an eruption in 1835, which destroyed several towns and villages.

15. S. Miguel Bosotlan, near the town of the same name, very active.

16, 17, 18, 19, lie between the city of Leon and the Gulf of Amapalla, viz.: —

16. Guanacaure, at the bottom of the gulf.

17. Cosiguina, or Gilotepe, near the same locality, which had an eruption in 1835.

Col. Galindo, in the 'Geographical Journal,' vol. v., and Mr. Caldcleugh, in the 'Philosophical Transactions' for 1836, have recorded, in terms which would have been almost applicable to the great eruption which overwhelmed Pompeii, the awful obscurity of the sky, which continued for forty-three hours consecutively; the vast showers of dust and pumice which enveloped every object over an extended area; the noise like that of artillery which accompanied the eruption; the melancholy howling of beasts; the flocks of birds of all species that came into the town, to seek protection, as it were, from man.

Amongst the physical changes induced, he mentions a primæval forest having disappeared—two new islands formed, one 800 yards, the other 200 yards long, consisting of pumice, earth, and pyrites, with a coppery smell—shoals produced in the sea, in one of which a large tree is fixed with its roots upwards—the river Chiquito, which ran towards the north-west, being completely choked up—and another river six yards broad having sprung up, which flows in the opposite direction to the former.

The British vessel Conway, cruising in lat. 7°, long. 105°, met with the same clouds of dust, apparently consisting of pumice, with many fragments also of the same stone floating through a space of nearly forty miles from north to south. The dust has been examined by Elie de Beaumont, who found only ten per cent. of it to consist of labradorite, the rest being ryacolite*.

18. Volcano del Viejo, near the same spot, 9000 feet high, is constantly smoking.

19. Telica, six leagues from Momotombo, is also in a state of constant activity.

* Comptes Rendus for 1837.

20. Momotombo, a very lofty mountain between the city of Leon and the lake of Nicaragua, which only emits smoke.

21. Masaya, near the lake of that name, was one of the most active vents at the time of the first discovery of the country. The Spaniards, says Juarros, call it Hell. Its flames were visible twenty-five miles off. Its crater was only twenty or thirty paces in diameter; but the melted lava "seethed and rolled in waves as high as towers." A story is told of a Dominican who imagined the fluid lava was melted gold, and descended into the crater with an iron ladle to carry some away; but the ladle, it is said, melted, and the monk escaped with difficulty. It is now tranquil.

22. Bombacho, an elevated mountain near the town of Grenada, which only emits smoke.

23. Sapaloca, on the lake of Nicaragua, opposite the preceding. It is probably the same with that which Malte Brun, on the authority of Gomara, 'Historia de las Indias,' calls Omo, which he says always continues burning, and which our sailors call the Devil's Mouth from this reason. (Scrope, p. 7.)

24. Papagayo, the same probably as Orosi, stated by Rouhault to be 9255 feet high.

25. Mirabeles, east of Rincon de la Vieja.

26. Tenorio.

27. Seropelas.

28. Zapanzas, nine leagues from the port of Velas.

29. Votos, above the town of Alajuela, 9235 feet in height.

30. Villa Vieja, north of the city of that name.

31. Cartago, near the town of that name, 10,774 feet in height.

32. Barua, at the bottom of the Golfo Dulce.

CHAPTER XXXI.

VOLCANOS OF SOUTH AMERICA, OR SOUTH OF THE ISTHMUS OF DARIEN.

General character of the Volcanos of South America—those of Quito—of Peru—Bolivian Andes plutonic—Cordilleras of the coast volcanic—Chili—Patagonia—Tierra del Fuego—South Shetland—General remarks.

The volcanos we are now about to consider are distinguished from those that most commonly meet the eye in Europe, not only by their gigantic proportions, but also by their general conformation and their mineralogical characters.

We have indeed described, as existing in Mexico and Guatemala, volcanos nearly rivalling them in point of elevation, and equally distinguished by their pyramidal forms, as well as by being made up of one uniform description of rock, and not of alternating beds of lava and scoriæ; but these characters are to be met with occasionally amongst the volcanos of the old world also, and are not stated to be accompanied, in the case of the Mexican volcanos, with any peculiar mineralogical composition.

In the Andes, on the other hand, we observe a long range of conical mountains, forming some of the highest eminences on the face of the globe, often destitute of craters, rarely pouring forth any streams of lava, but emitting from their summits only steam and aëriform fluids, whilst the material of which they are composed is that peculiar description of felspathic rock, which Henry Rose has distinguished, from the circumstance of its occurring in South America, by the name of *andesite*.

No wonder that Humboldt, the great and principal explorer of these extensive regions, should have felt himself privileged to protest against theories founded only upon an observation of the puny volcanos of Italy, and with a pardonable feeling of exultation at the wider field of induction which his own

superior opportunities of foreign travel had afforded him, should have compared the geologist who imagined all the eruptive rocks throughout the globe to be moulded according to the model of those he was familiar with in Europe, to the shepherd in Virgil, who supposed, in the simplicity of his heart, his own little hamlet to contain within itself the image of imperial Rome.

I have already stated, that *andesite* is a rock composed of crystals of albite, dispersed through a crystalline base of a darkish colour. Nevertheless, in that which is regarded more strictly entitled to the name, the mass has a white colour, and a friable texture, arising from the predominance of the felspathic portion, which is an admixture of albite and labradorite. Hence it may be regarded as the connecting link between the felspathic rocks with one and with three atoms of silica, the granitic and the trachytic series. With this felspar are associated crystals of hornblende, and sometimes of augite, whilst glassy felspar is found more rarely. When these predominate, the rock may be called a diorite.

It is probable that this substance, in conjunction with true trachyte, constitutes the greater part of the volcanic mountains destitute of craters that occur in South America. It varies however in different localities. Thus the summit of Chimboraço consists, according to Humboldt, of a semi-vitreous variety, with a basis like pitchstone, destitute of hornblende, but rich in augite, and possessing a schistose structure. Abich finds its specific gravity 2·646, and the per-centage of silica 67; but he states that hornblende, as well as augite, are present in it. Cotopaxi and Antisana both consist of andesite, with a predominance of albite and minute crystals of hornblende, in a dark grey, compact basis attracting the magnet. But a lava-stream that has flowed from the crater of the latter is intermediate between basalt and pitchstone. Pichincha is composed of a black variety of the same rock, resembling in its appearance pitchstone, in which 72·9 per cent. is albite, 17 or 18 augite and hornblende.

With respect to the geographical position of the mountains in which this variety of felspar predominates, it may be stated that the first indications of them, south of the Isthmus of Darien, occur between the second and third parallel of north latitude.

Hence there is an interval of nearly six degrees between the most southern of the volcanos of Guatemala, that of Barua, and the most northern of those in Quito, namely that of Rio Fragua, situated to the east of the sources of the Magdalena, which is said to be emitting vapours continually.

Next to this, in latitude 4°·35, is the Peak of Tolima, to the west of Santa Fè de Bogota, measured by Humboldt in 1801, and found to be 2865 toises in height, being the loftiest summit north of the Equator. It appears only to emit from its summit steam and gases, consisting of a small quantity of carbonic acid, but more sulphuretted hydrogen. It is remarkable for its distance from the sea, which is forty leagues off, as it lies in the central of the three chains which traverse New Granada from north to south. Roulin found records of an eruption which took place from it in 1595, and it appears to have returned to a state of activity in 1826. Boussingault relates, that on the 16th November 1827 the whole of New Granada, over an extent of more than 30,000 square leagues, was violently agitated, loud detonations were heard in the valley of Cauca at intervals of thirty seconds, and frequent rents occurred in the soil, from which gases were emitted. The rivers Magdalena and Cauca were impregnated with a muddy matter, smelling strongly of sulphuretted hydrogen. This also appears to be emitted in the neighbourhood, though accompanied with a larger proportion of carbonic acid, for the gas which escaped from fissures in the mica-slate formation from which the volcano was protruded, consisted of

Carbonic acid . . .	94
Sulph. hydrogen . .	1
Atmospheric air . .	5

3. The volcano of Puracé, east of Popayan, 15,985 feet above the sea; a truncated pyramid, composed on the summit of obsidian.

4. Sotara, south-east of Popayan, also rising above the level of perpetual snow.

5. Pasto, west of the town of that name, in lat. 1°·13 north. Its height is 12,621 feet. It is continually emitting smoke from its crater, in the bottom of which is a lake, and on its borders a dome entirely composed of sulphur, although the fumaroles exhale nothing but pure carbonic acid.

6. Azufral, situated a little further to the south in the same chain.

7, 8. Cumbal and Chiles, two volcanos almost immediately under the Equator, and constantly covered with snow. Cumbal rises to the height of 14,717 feet above the sea.

9. Imbaburu, near the town of Ibarra, a volcano which in 1691 poured forth a large quantity of mud accompanied with so many dead fish, that putrid fevers were engendered by the effluvia.

10. Pichincha, or Rucu Pichincha*, 17,644 feet in height, is situated eleven miles in a straight line W.N.W. from Quito. It contains two funnel-shaped craters, apparently resulting from two sets of eruptions; the western nearly circular and funnel-shaped, having in its centre a cone of eruption, from the summit and sides of which are no less than seventy vents, some in activity and others extinct, exhaling sulphuretted hydrogen and sulphureous acid gases, together with vast columns of black smoke. The only solid substance ejected of late is pumice, and it is probable that the larger number of the vents were produced at periods anterior to history. The eastern crater appears to be still more ancient, containing no traces of fumaroles. Previous to 1539, Pichincha was not known to be volcanic; but in that year, in 1577, 1587, and 1660, eruptions have issued from the existing cone, and it was in full activity in 1831.

11. Antisana, 17,956 feet in height, the only volcano in Quito where Humboldt observed anything analogous to a current of lava, which, as above stated, had much of the character of obsidian. Pumice and pitchstone are also seen on the slopes of the mountain.

12. Guachamayo, at the eastern foot of the chain, not far from the sources of the Rio Napo.

13. Sinchulagu had an eruption in 1660; its height is 15,420 feet.

14. Cotopaxi, one of the loftiest, as well as the most active of the volcanos of Quito. It is 17,662 feet high, and since 1742 has been almost in constant agitation, often pouring forth torrents of water.

15. Carguairazo, 14,706 feet in height, a mountain, the summit of which fell in on the 19th of June 1698, and at the same time gave out such torrents of mud, that the country for four square leagues round was covered with it. Immense numbers of small fish (*Pimelodes Cyclopum*) were washed down enveloped in the mud.

This volcano is situated in the immediate vicinity of Chimboraço, a mountain until lately considered the loftiest in the Andes, being 21,100 feet in height, and though not an active volcano, composed of volcanic materials.

Humboldt made an ineffectual attempt to reach its summit, attaining however the height of 18,097 Paris feet, and more recently Boussingault, in company with Colonel Hall, accomplished the ascent

* Quarterly Journ. of the Geol. Soc. No. 10.

so far as the foot of the prismatic mass of trachyte, whose upper surface, covered by a dome of snow, forms the summit of Chimboraço, —an elevation of 6004 metres (19,513 feet), the greatest which man had hitherto attained on mountains.

The whole of this enormous mass of rock appears to be of one uniform composition, nor is there the least vestige either of a crater, or of strata of lava and ejected materials making a part of its fabric.

Humboldt calls the rock an augite porphyry, consisting of labradorite and augite, but Von Buch considers it an andesite, composed of white crystals of albite and hornblende; and Abich infers, from a specimen brought by Humboldt from a height of 15,180 feet, that it is a true andesite, although the basis of the rock, which is of albite, includes pretty large crystals of apparently glassy felspar, together with hornblende, augite, and magnetic iron.

16. Tunguragua, in lat. 1°·41 south, 15,471 feet in height.

17. Sangay, in lat. 1°·45 south, 16,080 feet in height, is constantly disengaging vapours, and in 1742 emitted flames from its crater.

Such then is the series of volcanos comprised between the second parallel of north and the second of south latitude in the present republic of Columbia,—so numerous and so near one to the other, that Humboldt conceives that the high land of Quito, together with the neighbouring chain of mountains, constitutes one single swollen mass, an immense volcanic wall, stretching from south to north, the crest of which exhibits a surface of more than 600 square leagues. Cotopaxi, Tunguragua, Antisana, and Pichincha, are placed on this immense vault, and are to be considered rather as the different summits of one and the same volcanic mass, than as distinct mountains. The fire finds a vent sometimes from one, sometimes from another of these apertures. "The obstructed craters appear to us to be extinguished volcanos; but while Cotopaxi and Tunguragua have only one or two eruptions in the course of a century, we may presume, that the fire is not less continually active under the town of Quito, under Pichincha and Imbaburu *."

The connexion of the volcano near the town of Pasto with those of the province of Quito was shown in a striking manner in 1797. A thick column of smoke had proceeded ever since

* Personal Narrative, vol. iv. p. 29, Eng. Tr.

the month of November 1796 from the volcano of Pasto, but to the great surprise of the inhabitants of the city of that name, the smoke suddenly disappeared on the 4th of Feb. 1797. This was precisely the moment at which, sixty-five leagues further south, the city of Riobamba, near Tunguragua, was destroyed by a tremendous earthquake.

Volcanos of Peru.

The main chain of the Andes pursues its course in one uninterrupted line along the coast, from the high land of Quito to Peru, and until it reaches the latitude of about 15°, appears to be destitute of recent volcanos.

Here however, a little above the parallel of Arequipa, a bifurcation takes place, one portion of the chain still proceeding in a direction nearly parallel to the coast, the other sweeping at first round to the east, then proceeding southwards for about 400 miles, and afterwards near the famous city of Potosi bending westwards, so as to meet the main chain about the twentieth parallel of latitude.

Hence these two ridges include an immense alpine valley, that of Desaguadero, which lies 13,000 feet above the level of the sea, entirely bounded by mountains, and having no outlet towards the Pacific.

In the northern extremity of it lies the vast lake of Titicaca, occupying an area of almost 4000 geographical square miles, the islands and shores of which may be regarded as the cradle of Peruvian civilization *.

Now the colossal mountains which rise to the north-east of the lake of Titicaca, form, according to M. D'Orbigny, a distinct class, to which he has given the name of the *Bolivian system* †. The ridges of which it consists are composed of highly inclined beds of Silurian, Devonian, carboniferous, and triassic rocks. But the axis of the chain is of granite, which

* It was here, according to the traditions of the country, that Manco-Capac, the first Inca and lawgiver, to whom the Peruvians attribute their religion and their comparatively high civilization, miraculously appeared; and this accordingly was the central point from which their extended empire ramified in all directions.

† See the Report by Elie de Beaumont, of M. D'Orbigny's Researches, addressed to the Academy of Sciences at Paris.

appears to have elevated the former in a direction from N.W. to S.E., and consequently at a period later than that of the formation of the triassic group, so that the elevation of the Bolivian Andes dates from a period intermediate between this and the Jura limestone.

On the other hand, the western chain, or the Cordillera of the coast, is composed, in a great measure, of volcanos either active or extinct, which appear to have been upheaved at a much more recent period, and according to M. D'Orbigny, may at the time of their elevation have occasioned such a displacement of the oceanic waters, as caused them to overspread the neighbouring continent, and thus to have covered the surface of the land with mud and pebbles, as well as to have destroyed all the existing races of animals.

Hence the existence of that great Pampean formation which D'Orbigny and Darwin have described, and hence the occurrence in it of those large bones of Mylodon, Megalonyx, Megatherium, Platonyx, Toxodon, and Mastodon, which have lately been brought over, and have excited so much interest among zoologists.

Be that as it may, the plutonic rocks of the Bolivian Andes, and the volcanic of the Western Cordillera, are distinguished not only in age, but also in their characters. The former abound in metalliferous veins, amongst which those of Potosi are the most celebrated; the latter are entirely destitute of them; and whilst the one offers a succession of sharp rugged peaks and serrated edges, the other presents a number of those conical and bell-shaped summits which are so characteristic of rocks allied to trachyte.

Mr. Pentland* informs us, that the snowy chain of the Bolivian Andes rivals in height the Himalaya mountains themselves. Thus in lat. 16°·40, the *Nevado* of Illimani is probably 24,000 feet high, and the most elevated pinnacles of the snow-capped range which towers above the Indian village of Sorata, hence called the Nevado de Sorata, attains the enormous height of 25,250 feet.

The Cordilleras of the coast, though somewhat lower than those of the interior, appear in a few places to exceed in alti-

* *On the General Outline, &c., of the Bolivian Andes.* Journ. of the Geograph. Society, vol. v.

tude Chimboraço, as will be seen by the following brief statement of the principal mountains, all of which are volcanic in their origin, though some no longer continue active vents.

First, then, on the prolongation of the Western Cordillera, north of Arequipa, rise the *nevados* of Ambato and Corpuna, and about twenty miles from the same city the colossal *nevado* of Chuquibamba.

The latter bears a striking resemblance to Chimboraço as delineated in Humboldt's 'Atlas,' and appears to be formed, like this latter giant of the Columbian Andes, of one simultaneously uplifted mass of trachyte, which has pierced, and reposes upon, the subjacent secondary strata. The dome of Chuquibamba rises to an elevation of 21,000 feet, deduced from a measurement made by Mr. Pentland of that portion of the summit which surpasses the level of perpetual snow, assuming the latter to be 17,200 feet in this latitude.

In lat. 16°·24, towering over the populous city of Arequipa, rise three snow-capped mountains, viz. Pichu-Pichu, the volcano of Arequipa, and Chacani. The first and third of these form two elongated serrated edges, and probably constituted a portion of the walls of a very extensive elevation-crater, in which the second, that of Arequipa, was formed by eruptions of a more modern date.

This latter mountain presents to the eye a very regular volcanic cone, truncated on its summit, and rising to an elevation of 18,300 feet above the level of the Pacific. It has a deep crater, from which ashes and vapour are constantly seen to issue. These three nevados, like most of those in the Western Cordillera, are placed near its maritime declivity; but about ten leagues from the same point, in a south-eastern direction, and consequently further removed from the sea, is the volcano of Uvinas, a very extensive though shallow crater, where the Aborigines collect small masses of alum, used by them in dyeing. It has now ceased to burn, but in the sixteenth century produced an eruption that spread desolation for many leagues around. Its height exceeds 16,000 feet.

Meyen, a German traveller, reports, that a quartzose porphyry forms the base of this mountain, succeeded by red sandstone, but that on the table-land, which ranges at a height of 12,497 feet, nothing is seen but volcanic blocks composed of andesite with hornblende, or of obsidian containing also many crystals of albite and hornblende. Near the top, and above the snow-line, he found andesite to be the prevailing rock; and an American*, who reached the very summit, states that it was covered with pumice and obsidian,

* Samuel Curzon. Malte Brun, Nouv. Annales des Voyages.

so that these two substances appear to be produced from andesite as well as from trachyte.

Somewhat farther to the south rises the volcano of Chipicani, having a broken-down crater with an active solfatara in its interior, emitting aqueous and acid vapours, which by their condensation give rise to a considerable torrent, called the Rio Azufrado from the large quantity of sulphate of iron and of alumina which its water holds in solution. Its height is 16,998 feet.

Lastly, near Arica, in lat. 18°, are four stupendous volcanic mountains, the first of which, Anaclache, although the lowest of the four, is 18,000 feet in height. The second and third are called by the Creoles *Twins* (Melizzos), from the similarity of their form and the contiguity of their position, but by the Indians are distinguished by the names of Chungara and Parinacota. The most southern of these forms a perfect truncated cone, whilst the northern rather resembles a dome. Mr. Pentland thinks it probable that the latter is an active vent.

The most southern of the four is the magnificent *nevado* called Gualatieri, a volcano asserted by Mr. Pentland to attain an absolute elevation of 22,000 feet. With this the series, according to this writer, terminates; but Von Buch adds one other to the list, existing at a considerably lower latitude, viz. 21°·36. This is the volcano of Alicama, near the town of that name, the exact position of which however is not fully ascertained.

Von Buch states that this chain of mountains is separated from the sea by two or three smaller groups, possessing a height of 3000 feet. The first of these, not far from Arequipa, is composed of a rock having the same composition as andesite, but with the proportions of albite and hornblende reversed, so that it may be called a diorite. The large quantity of hornblende present in it, as well as its greater specific gravity, impart to it a character quite different from that of ordinary andesite.

The last of these groups is composed of a large-grained granite with red felspar, white quartz, and a little mica. Granite indeed seems to be confined to the base of the Andes, and never to rise to a high level.

Volcanos of Chili.

From the volcano of Alicama in lat. 21°·36, to Coquimbo in lat. 30°, no volcanos appear to exist, but in the interval the country is agitated by frequent and tremendous earthquakes. Thus the town of Copiapo was overturned by one in

1819, of which Captain Basil Hall * has given us a description. The earthquakes appear to recur periodically, at intervals of twenty-three years, judging by the fact that they visited the above-named town in the years 1773, 1796, and 1819.

The great number of the Chilian volcanos are known to us only by name; I am therefore able to do little more than to copy the list with which Von Buch has supplied us in his work on the Canary Islands so often referred to, which is as follows:—

1. Coquimbo, lat. 30°·5.
2. Limari, lat. 31°.
3. Choapa, lat. 31°·50.
4. Liguà, lat. 32°·12.
5. Aconcagua, perhaps the same as Liguà. Miers states that no eruption from it is known, though its form and elevation give it the character of a volcano.
6. S. Yago, called by Miers the Peak of Tupungato, probably rises to a height of 15,000 feet. It is situated to the east of Valparaiso.
7. Maypo, lat. 33°·53, of which Meyen has given a very interesting account.

It seems that the greater part of the mountain, to a height of 9000 feet, is composed of Jura limestone, recognized as such, by its Ammonites (*A. biplex*), *Exogyra Couloni*, and other characteristic fossils. Upon this are enormous beds of gypsum 700 or 800 feet in height, dolomites, and salt-springs, through the midst of all which the felspathic cone of the volcano rises, forming a great wall of very regular prisms 200 or 300 feet long, 50 or 60 broad, and 15 to 20 high. On the summit is a crater which cannot be reached on account of the snow which surrounds it, but which emits smoke and a light visible at night. No current of lava has been observed, but it is remarkable that on the road leading to the mountain accumulations of pumice exist, although this material is not found amongst the masses ejected from the volcano itself.

8. Rancagua, lat. 34°·15, which, according to Meyen, seems to be, like Stromboli, in a state of constant eruption.
9. Peteroa, lat. 35°·15, a very active volcano, examined also by Meyen, who finds the summit of the mountain on the ridge of the great chain composed of andesite, with numerous long crystals of hornblende, of a much darker colour than is in general found in volcanos, approaching to diorite. Molina records a most remark-

* Journal of a Voyage, &c.

able eruption which took place at it on the 3rd of December 1760, when the volcanic matter opened for itself a new crater, and a mountain in its vicinity experienced a rent several miles in extent. A large portion of the mountain fell into the Lontue, and having filled its bed, gave rise to a lake in consequence of the accumulation of the water *.

10. Pomahvida, lat. 35°·30. There are two peaks of this name, one of which is an active vent, situated near a lake, and belonging to a lateral spur, which detaches itself from the longitudinal chain running to the east; there is much uncertainty as to it, owing to discrepancies in the accounts given by various travellers.

11. Chillan, lat. 36°·5, situated on the termination of an elevated table-land of the Cordilleras, 14,000 feet above the sea.

12. Antuco, lat. 37°·40. Pœppig, who sojourned nearly a year at the foot of this volcano and ascended to its summit, gives a detailed account of it. It is at least 16,000 feet in height, and the cone would appear from Pœppig's description to be composed either of andesite or of a dolerite, being made up of augite and of white rhomboidal crystals of a felspathic mineral, probably albite. This cone is entirely encircled with steep escarpments of basalt, which, as in Iceland, seems to constitute a vast crater of elevation, through which this central conical mass has been protruded. No lavas have proceeded from the crater, which only emits steam and suffocating vapours, but lava-streams have frequently issued from the foot of the central cone. No obsidian or pumice has been observed on this volcano.

13. Callaqui, lat. 38°.

14. Chinale, lat. 38°·40.

15. Votuco, lat. 39°·20, situated on a lateral branch of the chain. It is a conical mountain, which ejects such a quantity of cinders and vapours, that according to an old traveller, nothing will grow within four or five leagues of it.

16. Villarica, lat. 39°·20, near the lake of the same name, the summit, says Molina, covered with snow, and in a state of constant eruption. This and a small volcano at the mouth of the river Repel, are the only *two* not included in the chain of the Andes.

17. Chignal, lat. 39°·55.

18. Ranco, lat. 40°·15.

19. Osorno, lat. 40°·35.

20. Guanegue, lat. 40°·50.

21. Quechucabi, lat. 41°·10.

22. Minchimadava, lat. 42°·45, opposite the islands of Chiloe.

* Hist. Natur. de Chili.

23. Medielana or Huayteca, lat. 44°·20.
24. St. Clemente, lat. 46°.

Here terminates the series of the Chilian volcanos, some of which are merely known from an old work of Ovaglia *, entitled 'Historica Relazione del Regno di Chile,' and from the large map of Cruz de Olmedilla.

But Mr. Darwin states that a deposit of white pumiceous conglomerate (or mud), accompanied abundantly with gypsum, extends, as he believes, for a distance of 570 miles, from Coy Inlet to San Josef, on the eastern coast of Patagonia †. It is probable therefore that volcanic forces, now slumbering or extinct, have been in operation also on the more southern portion of the continent, especially as Captain Hall observed a volcano burning in lat. 55°·3, to the north of Cape Horn; and as Mr. Darwin states, that although no recent volcanic district has been observed in any part of Tierra del Fuego, yet on the northern point of the island there were various ancient submarine rocks, consisting of amygdaloids with dark talc and agate, of basalt with decomposed olivine, of compact lava with glassy felspar, and of a coarse conglomerate of red scoriæ, parts being rendered amygdaloidal with carbonate of lime. The southern part of Wollaston Island, and the whole of Hermite and Horn Islands, seem formed of cones of greenstone; the outlying islets of Il Defenso and Don Ramirez are said to consist of porphyritic lava.

Andesite also occurs in large masses on both sides of the Beagle Channel; and the South Shetland Islands, south of Cape Horn, are stated to be volcanic. In one of these, the Island of Deception ‡, is repeated the singular phænomenon of alternations of layers of ice and of lava, regularly stratified, as has happened in one case on Mount Etna. It is apparently a crater of elevation, like Santorino, broken away on one side, through which the sea has entered, forming in the interior a lake about five miles in diameter, whilst that included by the semicircular crest of rocks which bounds it is about eight. This consists of perpendicular rocks 800 feet high, facing the internal cavity, and sloping more gradually towards the circumference.

* Rome, 1646. † Page 119.
‡ Journal of the Geogr. Society, vol. i. p. 64.

It is indeed curious to hear of hot springs gushing out from a rock built up in part of layers of ice.

Thus then a line of active volcanos may be traced at intervals from the 5th to the 46th degree of south latitude, together with remnants of extinct ones from thence to the most southern point of the American continent; whilst the intervening spaces exhibit, in the frequent earthquakes that occur, phænomena of an analogous kind.

This apparent communication, or at least similarity of constitution, subsisting between the several parts of this tract, is the more remarkable from the absence of all indications of volcanic action throughout the countries situated on the eastern side of the Andes, whether in Buenos Ayres, Brazil, Guayna, the coast of Venezuela, or the United States.

It is true there exist a little to the east of the Andes three small volcanos, situated near the sources of the Caqueta, the Napo, and the Morona, but these, in Humboldt's opinion, must be attributed to the lateral action of the volcanos of Columbia.

There is one remarkable phænomenon belonging to volcanos of the new world, which, though not altogether peculiar to them, is more frequent there than among those of Europe.

It often happens, that instead of ejections of lava proceeding from the volcano during its periods of activity, streams of boiling water mixed with mud alone are thrown out, as happened at Guatemala, Cotopaxi, &c.

It was once imagined that this mud and water were genuine products of the volcano, derived from some spot in the interior of the mountain, equally deep-seated with that from which the lava itself proceeds; but a fact recorded by Humboldt has done much to dispel this illusion.

I have already stated, that with this mud are often thrown out multitudes of small fish (*Pimelodes Cyclopum*), sometimes indeed in numbers sufficient to taint the air. Now as there is no doubt that these fish proceeded from the mountain itself, we must conclude that it contains in its interior large lakes suited for the abode of these animals, and therefore in ordinary seasons out of the immediate influence of the volcanic action.

Admitting the existence of these lakes, it is certainly most natural to attribute the water thrown out to the bursting of one of them, and the mud to the intermixture of the water with the ashes at the same time ejected.

The conclusions to which Humboldt has arrived from his observations on the physical structure of America*, of which only a part have as yet been fully brought before the public, are as follows:

All the most elevated points of the Cordilleras are of trachyte †, which rock encircles in zones a large portion of the table-land, but rarely extends into the plains. When the trachyte does not exist in sufficient quantity to cover the entire soil, it is scattered in small distinct masses on the back and crest of the Andes, raised in the form of pointed rocks from the bosom of the primitive and transition formations.

Trachytes and basalt are rarely found together, and there seems to be a mutual antagonism between these two classes of formations ‡. True basalts with olivine do not constitute beds interstratified with the trachyte, but when they are found near the latter they are superposed.

These and other volcanic formations, such as clinkstone, amygdaloid, and pumiceous conglomerates, are the principal rocks met with above the trachyte; sometimes however small local formations of tertiary limestone and gypsum occur.

But the circumstance which deserves to be considered with the greatest attention, as leading to the most important consequences, is the apparent passage from the trachyte into the porphyry beneath it.

This rock, which Humboldt considered as belonging to the transition series, is distinguished from the porphyries which are most common in the old world, by the almost entire absence of quartz, the presence of hornblende, of glassy as well as common felspar, and sometimes of augite. It would therefore be difficult to fix upon any absolute line of separa-

*Gissement des Roches, p. 327.

† Or rather of andesite, as has been since determined by H. Rose.

‡ This remark must be taken with very many exceptions, as Humboldt seems to allow (Gissement des Roches, p. 349).

tion between this kind of porphyry and trachyte; it is only from the union of all these mineralogical characters with the presence of obsidian, pearlstone, and scoriform masses, and from the relative position of the rock, that we can determine it to be trachyte.

It is also equally difficult to pronounce where the trachyte begins, and the porphyry which supports it terminates, for glassy felspar gradually becomes more and more common as we ascend to the upper strata of the transition porphyry, and beds even occur in it, which would be considered almost as characteristic of the trachytic formation*.

Thus between the porphyries which contain the rich silver-mines of Real del Monte, and the white trachytes with pearlstone and obsidian which compose the Mountain of Couteaux east of Mexico, an intermediate class of rocks occurs, which partakes of the characters sometimes of the older, and sometimes of the newer formation.

In South America likewise, the same remark applies to the strata intervening between the transition porphyry covered with black granular limestone, and the pumiceous trachytes constituting the active volcano of Puracè.

In like manner, in the very midst of the Mexican porphyry, so rich in gold and silver, we observe beds destitute of hornblende, but abounding in long narrow crystals of glassy felspar, which cannot be distinguished from the clinkstone porphyry of Bilin, in the trachytic district of Bohemia. In short, Humboldt considers that there is no more reason for admitting a *natural* line of separation between the transition porphyry and the trachytes of America, than there is between the transition limestones and those of secondary formation found above them in the old world.

I have already in Chapter V. made the same remarks with reference to the porphyries of Hungary, and have there shown that the difficulties here alluded to are a good deal lightened, now that the comparatively modern date of all kinds of eruptive rocks is admitted by geologists as at least a supposable case.

The porphyry which has led to these remarks is distin-

* Gissement des Roches, p. 121, *et seq.*

guished by Humboldt into two kinds; the more ancient, immediately covering the primitive rocks; the more modern, resting on slates and limestones belonging to the transition series. The former contains no metallic veins, the latter abounds in them. Both however possess the same characters, by which they become allied to the trachytes, just as the transition porphyries of Europe present many analogies to the red sandstone.

The older porphyry is found in South America immediately resting on the primitive rocks, and is covered by syenite, composed of hornblende and common felspar, with a little mica and quartz.

This syenite seems, in the province of Popayan, to pass into trachyte, the hornblende becoming more abundant, the mica more rare, and glassy taking the place of common felspar.

Sometimes, as at the foot of the volcano of Puracè, the syenite is separated by granite from the superimposed trachyte, which latter at top becomes glassy, and passes into obsidian.

The syenite is sometimes covered with a black limestone, so highly charged with carbon as to soil the fingers, and possessing all the characters of a transition rock, and yet the porphyry on which it rests has much resemblance to trachyte.

Humboldt also notices other circumstances which tend to establish a connexion between the older porphyry and the trachyte; thus the former rock at Pisoja is columnar, and at Rio Guachicon contains, like the trachyte of the Siebengebirge, fragments of gneiss.

Notwithstanding this, he seems afterwards to admit that it is questionable, whether these rocks are to be considered as belonging to the transition or to the trachytic series*.

These porphyries in Quito alternate with gneiss and mica-slate (rocks on which they usually repose), and are covered by trachyte, to which they present an approximation; hornblende and augite becoming more frequent towards the upper part of the formation.

The syenite associated with this porphyry also appears to

* Gissement, p. 135.

contain salt-springs, gypsum and sulphur, and is covered by a greenstone, consisting of felspar united with hornblende, and not with augite. Baron Humboldt considers this an additional proof, that the particular porphyry alluded to is not a trachyte, for the latter rock has hitherto been met with associated only with augite rock, and not with genuine greenstone.

The porphyry of Equinoctial America is covered by a formation of clay-slate passing into talcose slate, in which is situated the famous silver-mine of Guanaxuato in New Spain*. The thickness of this formation is no less than 3000 feet. It contains, as subordinate beds, not only syenite, but also serpentine and hornblende slate. No organic remains however have as yet been discovered. It passes into a siliceous slate, which has sometimes the characters of Lydian stone.

This rock is covered in Mexico by a second formation of porphyry, distinguished by its extreme uniformity, and containing rarely any subordinate beds. Its thickness is calculated by Humboldt at 5000 feet at the least. Between Acapulco and Mexico, it appears to be overlaid by a formation of compact limestone of a bluish-black colour, full of large caverns, and a case of the same kind is more distinctly observed at Zumpango, where the order of superposition seems to be—

1st. The primitive granite.

2nd. A compact, blue, cavernous limestone traversed by veins of calc-spar referred by Humboldt to the Zechstein, rather than to the orthoceratite limestone now regarded as Silurian.

3rd. Granite as before.

4th. Porphyry with glassy felspar, which in one place supports an amygdaloid of a semi-vitreous character, and in others two different calcareous rocks, both cellular, which, though evidently less ancient than that which rests on the granite, are certainly not so modern as the beds above the chalk.

The rocks too in the valley of Mexico, which, as I have

* Gissement, p. 153.

before observed, pass in one place into trachyte, are covered in another by a calcareous rock, which Humboldt considers to be at least as old as the limestone above alluded to.

On the other hand, the limit to the age that can be assigned to the metalliferous porphyry of New Spain is best determined by the appearances presented at Guanaxuato, where it is seen resting immediately on a transition slate with Lydian stone, and both rocks are alike traversed by the same metallic veins.

This is the very rock which I have before alluded to as possessing in many cases all the characters of trachyte, and yet it presents so many analogies to the preceding rocks which are covered by the older limestones, that Humboldt ranks it among the transition porphyries.

Below the Equator, between the fifth and eighth degrees of south latitude, Humboldt observed porphyries resting upon clay-slate, and apparently of the same age, which have sometimes much the aspect of basalt, containing more augite than felspar, and alternating with beds of jasper, and of compact felspar having a black colour and uniform consistence.

At other times the porphyries have less affinity to trachyte, as at the Indian village of San Felipe, where they are covered by a black shelly limestone.

Mr. Darwin however, in his recent 'Observations on South America*,' has clearly distinguished these two formations, the mutual relations of which Humboldt leaves somewhat undetermined.

He shows, that the shores of the Pacific for a space at least of 1200 miles, from Tres Montes in Patagonia to Copiapo in Peru, are composed of metamorphic schists, plutonic rocks, and clay-slate more or less altered.

On the floor of the ocean thus constituted, vast streams of various claystone and greenstone porphyries were poured forth, together with great alternating piles of angular and rounded fragments of similar rocks ejected from the submarine craters, which from their compactness seem to have taken place in profoundly deep water. The orifices of erup-

* Third Part of the Geology of the Voyage of the Beagle, p. 237.

tion appear to have been studded over a breadth of from 50 to 100 miles, and closely enough to form a continuous mass in Chili more than a mile in thickness.

After the cessation of the above eruptions, thick strata abounding in gypsum were deposited, and felspathic and other lavas occasionally were thrown out, whilst the sea became peopled with shells, which have left their traces behind them in the strata, and belong to the earlier stages of the cretaceous system.

The thickness of these submarine fossiliferous strata is such, as to indicate that a sinking must have taken place in the floor of the ocean during their deposition, consistently with those views of Mr. Darwin, which have been briefly alluded to in the 25th chapter of this work.

In central Chili, after the deposition of a great thickness of gypseous strata and their subsequent upheaval, a vast pile of tufaceous matter and submarine lava was accumulated, where the Uspallata chain now stands; and after all these successive formations had been completed, and the whole brought above the level of the waters, vast masses of andesite were upheaved along the line of an immense fissure extending north and south, where the Cordillera now runs.

Accordingly, the gypseous and porphyritic strata, being thrown into highly inclined or vertical positions by the protrusion of the igneous rock, constitute the highest peaks next to those consisting of andesite.

Mr. Darwin regards this upheaval as a slow and gradual movement; D'Orbigny, on the contrary, as a sudden and violent one; but however this may be, we are still at liberty to ascribe the differences beween the porphyries and andesites seen associated together in the Cordillera, to the submarine origin of the former, and the subaërial one ascribed to the latter formation.

[redacted]

PART II.

ON PHÆNOMENA NOT IMMEDIATELY ARISING FROM VOLCANOS, BUT SUPPOSED TO BE CONNECTED WITH THEM.

CHAPTER XXXII.

ON EARTHQUAKES.

1st. The Nature of the Earthquake-shock.—Earthquakes defined.—Three kinds of shock: undulating—succussive—and vorticose—examples of the three kinds.—Instruments for registering earthquake-shocks.—Central earthquakes—linear ones.—Duration of shocks—noises which accompany them—recurrence of shocks—diffusion of shocks through different strata—shocks felt at sea.—2nd. Dynamics of Earthquakes—Mr. Mallet's views stated.

In the preceding chapters of this work it has been my business to describe such phænomena only as seemed to stand in manifest and direct connexion with volcanic operations; and although, in investigating these, I was sometimes led on to allude to earthquakes, when coincident in point of time with the eruptions recorded, and even to such thermal waters as happened to lie contiguous to the theatres of the events detailed, yet no notice has hitherto been taken either of the one or of the other, except when their relation to the same deep-seated cause which displays itself in the workings of a burning mountain seemed obvious and incontrovertible.

To assume, without further inquiry, that because earthquakes and thermal waters are in some instances plainly volcanic effects, they must therefore be set down, wherever they occur, as having the same origin, would perhaps be precipitate; for it is evident that, although the ordinary operations of an active volcano can hardly fail to create an agitation throughout the contiguous country, as well as to elevate the temperature of its rocks, and consequently of the springs emanating from them, other causes are at least conceivable from which both the one and the other might result.

At the same time, it must be confessed to be agreeable to analogy, that an agent which appears to be of so wide-spreading a nature, and endued with such tremendous energy in its operations, if estimated merely by the effects which are seen to arise directly and immediately from it, should reveal

itself in other ways, either less imposing in their character, or less distinctly traceable to its workings. These latter however must not be neglected, if we wish to obtain a clear and comprehensive view of the effects of this mysterious force, and hence the consideration both of earthquakes and of thermal waters ought to precede any inquiry that may be undertaken into the theory of volcanic operations, in order to establish, first, whether they are always, or if not always, in what cases they are to be set down as relevant to our present subject; and secondly, to what new conclusions they are capable of conducting us, with respect to the localities in which volcanos reside, or the nature of the force which is exerted by them.

Under the name of Earthquakes, then, we understand movements of portions of the land by a force operating from below upwards, the seat of which is placed beyond the sphere of direct observation.

We do not therefore include within our definition all movements or dislocations of the earth's surface, such for instance as land-slips, caused by the failure of support from beneath, by the pressure of water, or by the effects of storms.

These phænomena are all clearly unconnected with volcanic action, and therefore do not at all belong to the subject we are discussing; neither are they *in common parlance* referred to earthquakes, which, in their ordinary acceptation, imply the operation of some more deeply-seated cause.

In the greater number of cases indeed, earthquakes produce shocks and undulations of the ground of inconsiderable force, succeeding each other rapidly and in an irregular manner. But as these, frequent as they may be, leave behind them no permanent traces, they have been but rarely noticed or registered. Occasionally however, when the force exerted is greater, such commotions of the earth arise as are not only destructive to the works of man, but even affect the very configuration of the country, and hence are calculated to produce a deep and lasting impression upon the minds of the inhabitants.

In Southern Italy, where this is too often the case, the movements of the earth referred to earthquakes having been carefully observed, are divided into three kinds:—

1st. The undulatory motion, which takes place horizontally and heaves the ground successively upwards and downwards, proceeding onwards in a uniform direction.

2nd. The successive motion, in which the ground is heaved up in a direction more or less approaching to the perpendicular, as happens in the explosion of a mine.

3rd. The vorticose motion, which seems to be a combination of the two preceding ones, several undulations taking place contemporaneously, and thus interfering one with the other, so that during its continuance the surface of the land is tossed about somewhat in the same manner as that of the sea is during the prevalence of a storm, when a number of billows travelling in different directions strike one against the other, and thus produce every possible complexity of movement.

Of these three kinds of earthquake-shocks, the first is the most common and the most harmless. From the second, that of succussion, more is to be apprehended; but the vorticose movement is the one which has been felt in the most violent and disastrous catastrophes on record.

By earthquakes indeed of the two latter kinds, not only have the frail works of man's creation been annihilated, but even mountains have been rent asunder and valleys produced. If these then can be proved to be connected with volcanos, we should omit some of the most important and wide-spreading effects of the force under consideration, were we to pass them over in our review of the phænomena.

Now this second kind of movement has been noticed with greater or less distinctness by many of those who have observed and reported to us the frightful earthquakes which, on the 1st of November 1755, brought about the destruction of Lisbon. Of the not less terrific, though less widely diffused earthquake, which in February and March 1783 laid waste Calabria and Messina, we have also obtained authentic accounts. Dolomieu*, who made observations on it at the very time and place where it occurred, states distinctly, that the movements of the principal shock on the 5th of February were always of a wave-like character, and could be compared

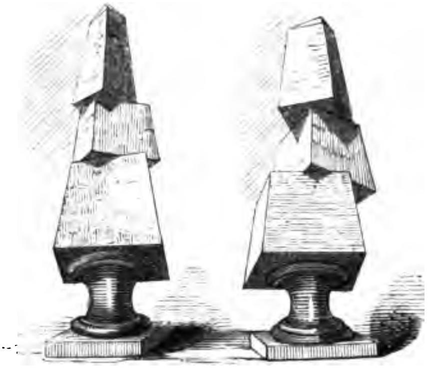
* Dissertation on the Calabrian Earthquake.

to nothing better than to the effect produced, when we place small quantities of moist and slightly moistened sand near each other on a plate which we toss vertically upwards, moving it horizontally at the same time backwards and forwards.

On the 28th of March of that year, a fine example of a movement of succussion was perceived; for, according to Hamilton's account, the summits of the granitic hills in Calabria were clearly seen to rise and fall alternately, and individuals, and even houses standing by themselves, are said to have been suddenly borne aloft, and then, without any damage being done to them, brought back to a somewhat higher spot than before.

Dolomieu says, that the foundations of many houses were in a manner ejected from the ground, their stones shattered one against the other, and the mortar between them ground to powder.

Nevertheless certain effects which were brought about by this earthquake would seem to place it in the category of a vorticose movement. Thus two obelisks, placed at the extremities of a magnificent façade in the convent of St. Bruno, in a small town called Stefano del Bosco, were twisted in a most remarkable manner—the pedestal of each obelisk remaining in its original place, but the separate stones turned partially round, and removed sometimes nine inches from their original position without falling, as represented in the following woodcut*:—



Obelisks belonging to the Convent of St. Bruno.

* Trans. Royal Acad. Naples, quoted by Lyell, Princ. of Geol. vol. i. p. 418.

In the earthquakes which, on the 26th of March 1812, ravaged the Caraccas, the ground experienced a continued undulatory movement, and seemed to heave up and down like a boiling liquid. This was followed by a perpendicular movement of three or four seconds, followed by a second undulatory movement of somewhat longer duration. The shocks were in two opposite directions, namely from north to south, and from east to west, and nothing could resist this conjunction of a vertical with two horizontal movements crossing each other. This then may be regarded as an example of the *vorticose* description of shock*.

The most frightful however of these catastrophes was the earthquake which, in June 1692, ravaged the whole of Jamaica. At Port Royal † the entire surface of the ground seemed at the time like a rolling swelling sea; houses were shifted from their places; men who, at the commencement of the phænomena, had escaped into the streets and open spaces of the town, were thrown down, tossed to and fro, and often bruised and stunned in the most frightful manner; others again thrown aloft and borne to a great distance, so that some by good fortune were carried out into the harbour, and falling into the water escaped with their lives.

If the movements of the ground are only simple and wave-like, they follow very remarkably one exact line. To ascertain this with accuracy, as the reports of eye-witnesses can seldom be depended on, instruments called Seismometers have been invented. The most rude and simple of these is a basin partly filled with treacle, or any other viscid liquid, which on the occurrence of a shock capable of disturbing the equilibrium of the building in which it is placed, would be tilted on one side, and cause the liquid to rise in that direction, when a portion of it would adhere, and show by its height above the surface the degree of disturbance that had taken place. But it seems probable, that the time necessary to overcome the *vis inertiæ* of a liquid like treacle would exceed the duration of the shock, so that this method must be regarded as uncertain and inaccurate.

* See Humboldt's Pers. Narr. vol. iv. p. 13. † Phil. Trans. vol. xviii.

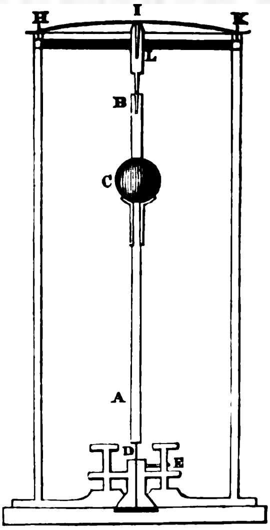
Another method proposed is to employ a pendulum provided with a bit of chalk, which should mark on a ruled board the extent of its ordinary oscillations. Any earthquake-shock would throw it from its centre, and the degree of deviation would be marked upon the board by the chalk.

Professor John Forbes has invented an improvement upon this instrument, of which he has given a description in the Edinburgh Philosophical Transactions *.

It consists of a vertical metal rod A, B, having a ball of lead C, moveable upon it. It is supported upon a cylindrical steel wire D, which is capable of being made more or less stiff by pinching it at a greater or lesser length by means of the screw E.

A lateral movement, such as that of an earthquake, which carries forward the base of the machine, can only act upon the matter in C through the medium of the elasticity of the wire, and the direction of the displacement will be indicated by the plane of vibration of the pendulum.

The following wood-cut gives a section of this instrument of Professor Forbes's invention :—



* vol. xv. part. 1.

The self-registering part of the apparatus consists of a segment of a sphere H, I, K, made of copper and lined with paper, against which a pencil L, inserted in the top of the pendulum-rod, is gently pressed by a spiral spring. The marks thus traced on the concave surface indicate at once the direction and greatest extent of the pendulum's vibration.

Mr. Mallet* has invented a very ingenious form of apparatus adapted for registering both the vertical and horizontal movements, but one whose use will be limited by the necessity of employing a constant galvanic battery. Were earthquake-shocks as frequent in their occurrence as rain, wind, and other meteorological phænomena, the necessity for constant vigilance would be the means of maintaining the instrument in working order; but when they happen only three or four times a year, or even less, an apparatus that requires such frequent overlooking would scarcely fail to be neglected, and therefore might not be available at the time wanted. Seismometers have not as yet been much employed in countries where shocks are frequent; but within the last few years a register of those felt at Comrie in Perthshire has been kept by the aid of these instruments, so that the force and duration of some of these movements are *now* determined†.

It seems to be well ascertained, that a great number of the most remarkable earthquakes spread over the surface round a common centre in a concentric form, like the ripples on the surface of water when a stone is thrown into it, or like the shocks arising from the explosions of a mine.

Such, according to the account given of it by Hamilton ‡, was the case in the great earthquake of Calabria, the focus and commencement of which was the most southern district of Calabria, from its extreme point, Capo delle Armi, as far as the contracted portion which lies between the two bays of Euphemia and Squillace.

* Dynamics of Earthquakes, Proceedings of the Royal Irish Academy, vol. xxi. p. 1.

† British Association Reports, vol. xiii. p. 83.

‡ Phil. Trans. vol. lxxiii.

This part of Italy is separated from the rest of the peninsula by a wide flat tract of ground about twenty-four miles long and six or eight wide: within this space was concentrated the first and most violent of the shocks, which made such fearful ravages about the little town of Oppido. Next in violence were the shocks which took place at Messina; and even farther off, in the Lipari Islands, according to Spallanzani, the effects were very remarkable*.

The circumstances were very similar in the case of the earthquake of Lisbon, the *focus* of which unhappily seemed to lie almost underneath that populous city†.

Here also shocks were experienced in all directions round this central point, as at the Azores, at Cadiz, in several parts of England, and even more slightly in Switzerland.

This earthquake affords the best example on record of the extent of ground over which some of these great natural convulsions diffuse themselves. It has been computed, that the above-named shock pervaded an area of 700,000 geographical miles, or the twelfth part of the circumference of the globe, comprising all the Spanish peninsula—being felt at Cadiz, Gibraltar, Malaga, Madrid,—and extending to the Pyrenees and to Provence.

Shocks sufficient to damage houses were ex erienced at the same time in many parts of the Alps; slighter ones at Geneva and Neufchâtel; but at Como, Turin and Milan, taking place with considerable force. Vesuvius, which had shown signs of commotion previously, became tranquil on the day of the earthquake.

North of the Alps it was noticed at Augsburg; the hot springs of Töplitz were disturbed at the same time, though the neighbouring ones of Carlsbad continued unaffected; nay, even in Norway and Sweden the lakes were observed to be in a state of commotion.

At Gluckstadt, on the borders of the Elbe, the sea rose and sunk in a remarkable manner; in Cornwall the waters rose as much as eight or ten feet, and swept away several small vessels; whilst on many parts of the coast the same phænomenon was observed, and even in Scotland the waters

* Dolomieu, p. 57. † Phil. Trans. 1755.

of Loch Lomond, Loch Ness, Loch Katrine, &c., rose above their banks.

On the opposite side, many places in Morocco, such as Tetuan, Tangiers, Fez, &c., were overturned, and shocks were experienced in the Canary Islands and the Azores.

But what was more remarkable, the West Indian Islands sympathised in the movement, and the sea surrounding them assumed a black tint, perhaps from bitumen, whilst at the same time Boston, New York and Philadelphia were sensibly affected.

Another central earthquake was the one which befell the Rhenish provinces and the Netherlands in 1828*. It was then remarked, that the strongest shocks were in the neighbourhood of Brussels, Waterloo, Liège, and Maestricht, in a space which had the form of an ellipse. From this central point the shocks radiated from east to south-east in Westphalia, and west to Middelburg and Vliessingen.

More commonly, however, the direction of volcanos is linear, and coincides with that of some chain of mountains.

Even in the earthquakes of Calabria already referred to, a certain tendency to a linear movement may be traced; for although the first and most severe of the shocks experienced appeared to have for its centre Oppido, and was felt not only by the district to the north, south, and west, but also by that to the east of this spot,—notwithstanding the intervention of the Apennine chain,—for the town of Gerace suffered severely, yet of the shocks that succeeded, the first had its *focus* at Soriano, and the second at Girifalco, both which places lie, like Oppido, upon the western flank of the mountain ridge, and along a line which, if prolonged to the south, would intersect the latter locality.

Hence it would appear, that even in *central* earthquakes the impelling force is situated along a particular line of country, although at the points at which it is exerted in its greatest intensity, the vibrations are propagated with greater or lesser violence in all directions round.

Palassou, who has described the earthquakes of the Pyre-

* Poggend. Ann. xiii. Nöggerath has also given an account of the same.

nees, remarks, that they in general follow the direction of that chain from W.N.W. to E.S.E.

Gray* has pointed out, that those which took place in England in 1795 were from south-west to north-east, parallel to the direction of the strata.

In equinoctial America the same law seems to prevail still more constantly. But there are here two lines of mountains: one that of the Cordilleras, which runs from north to south; the other placed nearly transversely to the former, extending from the island of Trinidad along the coast of New Andalusia, Venezuela, Caraccas, to New Granada, nearly from west to east.

In a line with both these ranges frightful earthquakes have occurred, as at Lima, Callao, Riobamba, Quito, Pasto, Cumana, Caraccas, &c., by which 40,000 persons have been known to be at one time destroyed†. In all these cases the greater effects have not only been confined to the range of mountains, but have pursued the direction of the coast.

Thus, in the dreadful earthquakes which in 1746 destroyed Lima and Callao, the shocks followed this line from north to south. In the last great earthquake which took place in 1822, Miss Graham reports, that the ground seemed to her to be heaved up in the same line, and Humboldt states the same with reference to the earthquake of Cumana in 1797, and to others.

In some rare cases earthquakes have taken a course *across* the line of the mountains, but the shocks are then generally weak. In the Apennines one occurred in 1828 across from Voghera, by Bocchetta, to Genoa‡. Other instances are given as happening in the Cordilleras§, and in the Tyrol‖. Thus at Mendoza, a city situated on the eastern side of the Cordilleras, the great earthquake of 1835, which destroyed Conception, was felt¶, although it did no damage.

* Phil. Trans. vol. lxxxvi.
† Humboldt's Personal Narrative.
‡ Poggend. Ann. vol. xxv.
§ Humboldt's Personal Narrative, vol. iv.
‖ Von Hoff, Pogg. Ann. vol. xviii.
¶ Darwin, Geol. Trans. vol. v.

The range of country along which linear earthquakes extend, though perhaps not equal to that which has been observed in what have been called central ones, is nevertheless very considerable. Thus those of Chili are stated by Humboldt to extend as high up as the Gulf of Guayaquil, along a range of 600 leagues.

Darwin, in a masterly paper in the Geological Transactions, vol. v., has discussed the evidence in favour of the coincidence between those great physical convulsions which occurred in the years 1834 and 1835 in South America, and concludes that the cause which produced the earthquake at Conception, affected the coast along a line of more than 2000 miles.

In like manner in the shock of 1837 which took place in Syria, the vibration was felt "on a line 500 miles in length by 90 in breadth."

The duration of earthquakes is in general very short in comparison with the destruction which they occasion. The catastrophes which have ruined whole cities and provinces are indeed the work almost always of a single instant*. The Caraccas were destroyed by three shocks, each lasting about three or four seconds, and the whole not occupying the space of a minute. In Calabria that of 1783 lasted only two minutes, and that of 1692 in Jamaica was completed in three. The dreadful one at Lisbon lasted about five minutes; but the first shock, which was the worst, occupied only from five to six seconds.

The most terrible destruction of life is occasioned by those earthquakes that take place without any previous warning, as was the case at Lisbon, where, as the shock happened about nine o'clock in the morning, on the Feast of All Saints, almost the whole population was within the churches, owing to which circumstance no less than 30,000 persons perished by the fall of these edifices. That of Calabria and of Lima was equally unexpected, and therefore equally fatal. In general however a slight shaking of the ground precedes the more violent shocks, and in countries subject to earthquakes it is the custom with the people, on the least agitation

* Humboldt's Personal Narrative.

of the ground, to run out of their houses, and take shelter in some open space at a distance from all buildings. In Sicily an alarm-bell is rung when any such sensation is experienced.

The earthquake is often preceded or accompanied by a subterranean noise, which has been compared to the rolling of thunder. Humboldt says it consists of slight detonations, following each other with greater or lesser rapidity. That it is propagated through the ground, and not through the air, appears from its being sometimes heard in wells and mines when not audible on the surface. Unlike sound propagated through air, it seems to reach spots at different distances one from the other at the same instant of time. Of this Humboldt* gives several examples.

The same writer often alludes to the remarkable underground thunder which was heard at Guanaxuato in 1784, from the 9th to the 12th of February, not followed by any earthquake, and which in other places creates as little alarm as summer lightning with us. Burchell mentions having heard explosions like those of a cannon at the Cape of Good Hope; in this instance also not the forerunner of any earthquake. Of these subterranean noises, some of the most remarkable were those heard at the island of Melida, opposite Ragusa in Dalmatia†.

In March 1822 the inhabitants were startled for the first time by a noise, which was mistaken for a cannonading either at sea or on the neighbouring coast; but this not proving to have been the cause, they were obliged to refer it to some subterranean movement underneath their island. It continued at intervals, and on the 23rd of August 1823 was followed by an earthquake, by which a portion of one of the highest mountains in the island was severed from the rest. The recurrence from time to time of these noises caused so much alarm, that the inhabitants thought of emigrating in a body to the continent of Dalmatia. In consequence of this, two naturalists, Partsch and Rieppell, were sent by the Austrian government to report upon the facts; they remained a month on the island, during which time they heard these

* Personal Narrative, vol. iv.

† Hoffman, Hinterlassene Werke, p. 331.

detonations on seven days, on one of which there was a slight earthquake.

The Commissioners on their departure expressed their opinion that there was no ground for alarm; nevertheless, the detonations have continued from time to time, and if the report given in a recent journal* be correct, it would appear that in 1843 an active volcano broke out in the island.

In countries that have experienced one destructive earthquake, a recurrence of minor shocks is for some time afterwards to be apprehended. Humboldt states that after the dreadful one of Cumana, in 1766, the earth was agitated for fourteen months consecutively, so that the wretched survivors were afraid to rebuild their ruined habitations. At Lisbon, in 1755, the shocks continued from the 1st of November to the 9th of December, when an earthquake occurred not much inferior in point of violence to the first.

Spallanzani† states the same thing with respect to Calabria, and other writers to those of Lima, Caraccas, and the West Indian Islands.

No description of rocks appears to be exempt from earthquakes; thus the granite, gneiss and mica-slate of the Cordilleras are affected equally with the secondary rocks of the Italian mountains and the tertiary formations of Sicily, a proof that the processes which occasion these catastrophes lie deeper in the bowels of the earth than the extreme limit to which the above rocks extend, and may consequently pervade them all in an equal degree.

Nevertheless, there is a difference between the mode of propagation of the earthquake-shocks, connected with the nature of the rocks through which their course lies.

It is reasonable indeed to expect, that in a uniform, unbroken range of mountains, undulations should spread equally all around, like the ripple on the surface of a pool of water; but that when the rocks are divided into tabular masses, between which cavities and fissures exist, or when loose and irregular blocks are interposed between the strata, there would

* Jameson's Journal, vol. xxxvi. p. 202, on the authority of the Gazzetta di Milano.

† Voyages dans les deux Siciles.

be a variation in the relative intensity of the shocks in one direction and in another.

The history of earthquakes fully confirms this expectation. It is in general remarked, that the shocks are less destructive on hard rocks than on those of a loose consistence. Thus at Messina, that part of the city that lay on alluvial or tertiary rocks was more damaged by the earthquake than the other which had for its foundation granite*.

Similar instances are given in the cases of Jamaica, the Pyrenees† and Calabria, and this irregularity in the transmission of the shocks may account for earthquakes being experienced in one locality, whilst another near it escapes entirely. In countries exposed to earthquakes there are certain spots which seem always affected, and others always exempt from the catastrophe, and the latter are called by the natives of South America *bridges*, an expression by which they intimate their belief that nature has stretched some unyielding material over the stratum which propagates the shocks‡.

Sometimes however this source of security fails, for the peninsula of Araya, which had for many centuries escaped the earthquakes that had afflicted Cumana, became itself the very focus of the one§ which took place in 1797.

It had been remarked by the ancients‖, that hollows of any kind, such as grottos, wells, quarries, tend to preserve from destruction houses placed over them. With this impression the Romans made deep excavations underneath the Capitol, in order to preserve that part of their city from the shocks of earthquakes; and Capua, which abounds in deep wells, has suffered less than any town in its vicinity from this cause.

Poli¶ ascribes to this circumstance the exemption which Naples enjoys, and as to other parts of the globe a similar remark has been made.

The agitations are not confined to the land, but are often

* Spallanzani. † Palassou.

‡ Such at least is Humboldt's explanation, but Darwin explains it differently. See his paper in Geol. Trans. vol. v. p. 622.

§ Humboldt's Personal Narrative, vol. ii.

‖ Pliny, Hist. Nat. lib. ii. cap. 82. Seneca, Nat. Quæst. lib. vi. cap. 4.

¶ Memoria nel Tremuoto di 26 Juglio 1805.

felt also at sea. Thus in the earthquake of Lisbon, about an hour after the most violent of them, the sea suddenly rose on the mouths of the Tagus, and, though the ebb had begun two hours, and the wind blew off land, attained the height of forty feet, sweeping away 3000 persons from the quay where they had taken refuge to avoid the fall of the houses in the town, receding again as quickly, and then returning three or four successive times, although with diminishing force on each occasion. The whole west coast of Portugal suffered from this rise of the sea, which at Cadiz amounted to sixty feet.

Similar occurrences are related at Jamaica, Lima, and Messina. At the last place the Prince of Scilla and about 1400 men who were with him, some in boats, others standing on the coast, were swept away by one great wave. In some cases ships at sea have felt shocks, which have made all on board believe they had struck upon a rock.

We have now considered the nature of the movement propagated through the ground, by each of the three descriptions of earthquake popularly distinguished by those nations, which have enjoyed the unenviable privilege of observing them most frequently.

But although in a treatise of this description we have principally to deal with facts, upon which to ground certain general inferences, with respect to the connexion of these phænomena with Volcanos, and the light which they are capable of shedding upon the operation of this Force, it may not be uninteresting or uninstructive to touch briefly on another branch of the subject, belonging perhaps more properly to the mathematician than to the naturalist, in which the various modifications of earthquake-shocks, and the several modes of their propagation, are referred to one common principle, and explained in accordance with mechanical laws. This is a question altogether independent of the one which will be afterwards discussed concerning the original cause of the earthquake itself;—it takes up the inquiry at the point to which I have brought it in my preceding remarks, and seeks to learn merely what kind of motion, however produced, that must be, which will fulfil the requisite conditions observed, namely—

that it shall move with such an immense velocity as to displace bodies by their inertia—that it shall have a horizontal, alternate motion, either much quicker in one direction than in another, or different in its effects—and that it shall be accompanied by an upward and downward motion at the same time.

This particular branch of the inquiry was formerly pursued by Mr. Mitchell, of Queen's College, Cambridge, in a paper published in the Phil. Trans. for 1760.

He there suggests, that the motion of the ground during an earthquake-shock is due to a wave propagated along its surface from a point where it has been produced by a sudden impulse. This impulse he conceives to arise from the rapid production or condensation of aqueous vapour, under the bed of the ocean, brought about by the agency of volcanic heat.

Mr. Mallet, in an elaborate paper lately published in the Proceedings of the Royal Irish Academy, which has been already referred to, attempts to follow out the consequences that would result from an impulse of this kind imparted to the solid strata of the earth, according to the known laws of waves or pulses in aëriform, liquid and solid bodies.

First then, the original impulse may either be on land, as in a volcanic region situated in the heart of a great continent or island, or it may lie beneath the bed of the ocean. The latter Mr. Mallet considers to be the more frequent, and the more formidable, because on land there are vents provided, which prevent the exertion of the same force that comes into operation at the bottom of the sea.

Now in the former case an elastic wave is propagated through the solid crust of the earth as well as through the air, and transmitted from the former to the ocean water, where it is finally spent and lost.

In the latter case, on the contrary, the original impulse comes from under the ocean itself, and consequently three sorts of waves are formed and propagated simultaneously; namely one or more successively through the land; one through the air, producing a sound like the bellowing of oxen, the rolling of waggons, or distant thunder; and a third upon the surface of the ocean, which rolls in to land, and reaches it long after the shock or wave through the solid

earth has arrived and spent itself. There is also a fourth wave (of sound merely) propagated through the mass of the ocean water likewise, with a velocity far greater than the former, which will reach the land, and be heard there as a sound, long before the great surface-wave will have rolled in.

With regard to the first of these, namely the earth-wave of shock, it may be remarked, that we have abundant instances of vibratory motions propagated through solid matter with immense velocity. Thus any powerful blow, such as the letting down of the roof of a colliery, the fall of a large stone, such as one of the large masses at Stonehenge, and the explosion of a powder-magazine, has been known to cause a vibration like an earthquake felt to a great distance. The earth-wave, while passing under the deep water of the ocean, gives no trace of its progress; but when it arrives in soundings, and gets into water more and more shallow, it causes an undulation also upon the surface of the water. Thus the earth-wave, when it approaches the shore, is attended with a small sea-wave; but as its velocity is very great, it slips, as it were, from under the latter, and produces a momentary elevation of the beach at the time of its reaching it, owing to which the sea-wave which follows in its wake *seems* to recede from the shore in the first instance, and immediately afterwards to flow up higher than the usual tidal mark. This may explain the recession and subsequent rise of the sea *at the period* of the occurrence of an earthquake. When the earth-wave passes abruptly from a formation of high elasticity to one of low elasticity, or *vice versâ*, it will be partly reflected, a wave being sent back again, producing a shock in the opposite direction; and partly refracted, or its course changed; and thus shocks will occur both upwards and downwards, and to the right and left of the original line of transit.

Hence shocks are found to do most damage at the line of junction of the deep diluvial plains with the slates and granites of the mountains, as was the case in Calabria.

I proceed next to the great sea-wave, which, though generated at the same moment as the earth-wave already discussed, travels more slowly, and therefore arrives at the coast some time after it, as has been remarked by Darwin. The damage done by this will be greater when the coast is shallow, because

when the depth of the sea close to land is not equal to the elevation of the wave, the latter will topple over and form breakers, whereas in deep water it will only spread itself upon the rocks. In the former case it will be divided into several waves, according to the height of the original wave and the depth of the water; in the latter it will be single. The great sea-wave may likewise be distorted by change in the depth of water, as the earth-wave may be by change of strata, &c., and hence they may not be felt on the same part of the coast. The fissures caused in the strata by an earthquake, which are sometimes permanent, but more frequently close up again immediately, Mr. Mallet explains by the strain produced by the earth-wave in the course of its propagation. The amount of the fissures will be determined by the degree of elasticity of the rock itself; so that a shock passing through a crystallized igneous rock of great elasticity, and consequently not liable to fracture, may become spread over more space, and thus be weaker in comparison to what it had been previously, or become afterwards, when transmitted through strata where the elasticity was less.

But how are we to explain the converse of this, namely the fact that earthquake-shocks from a distant quarter, or from a great depth, are felt in crystalline, whilst unperceived in soft stratified rocks?

Mr. Mallet refers this to the principle, that the latter, although more affected by a shock, do not propagate it so far; hence the wave is transmitted by crystalline rocks to a greater distance than through stratified ones.

Without following Mr. Mallet in his detailed explanation of the various accidents of earthquakes, arising from *interferences* in several waves, and from other causes of the same kind, I will just recapitulate the order of the successive phænomena which present themselves, according to this writer, in the case of an earthquake affecting a maritime tract.

First, we have the earth-sound wave, and the great earth-wave or shock; the sound-wave through the air; the sea-wave occurring at the time, which he calls the forced sea-wave; and the great sea-wave; all originating at the same moment, and produced by one impulse.

The sound-wave through the earth, and the great earth-

wave or shock arrive first, and are heard and felt on land, accompanied, as far as the beach, by the small sea-wave called the forced sea-wave; these are almost instantly succeeded by the sound-wave through the sea; next arrive the aërial waves of sound, and continue to be heard for a longer or shorter time, and finally the great sea-wave rolls in upon the shore.

Such is the sequence of phænomena when the earthquake takes place under the bed of the ocean: when it occurs on land, the great sea-wave is necessarily wanting, although disturbances may occur in consequence of the falling of masses of rock into the water, which may be mistaken for it.

The velocity of the land-wave and that of the accompanying sea-wave being ascertained, it would seem possible to determine the distance (out of sea) from the spot affected at which the earthquake originated. But the former will vary with the nature of the rock through which it is transmitted, for the harder and more elastic the rock is, the greater will be the velocity of the earth-wave produced, and *vice versâ*.

Now whilst the elasticity of cast-iron is 5·895, that of limestone varies from 2·400 to ·635—slate being 7·800—Portland stone, 1·570—white marble, 2·150. From these data we may calculate that the velocity of the wave-transit per second—

	Feet.	Miles.	
in Limestone (soft lias) was	3640	40	per minute.
Sandstone	5248	57	„
Portland stone . . .	5723	63	„
Marble	6696	73	„
Carboniferous limestone	7075	78	„
Clay-slate	12757	140	„

Now the observed speed of the great Lisbon earthquake, according to Mitchell, was only 1750 feet per second, the difference being assignable to breaches of continuity and other causes of retardation. The sea-wave on the contrary had not one-tenth of that velocity, or did not travel more than 175 feet per second; so that if the interval of time between the two was, as is reported, half an hour, the focus of the impelling force would have been about sixty miles distant from the land.

It will be perceived, that we have here spoken of only one *kind* of movement, namely an undulatory one, instead of the three which have been above distinguished; but this is be-

cause, according to the views of Mr. Mallet, they may all be reduced to this one. The undulatory and vertical he imagines to differ one from the other only in the magnitude of the earth-wave produced. If this be small, a horizontal motion will alone be perceived; when great, a vertical as well as a horizontal shock are occasioned. I must however refer my readers to Mr. Hopkins's forthcoming memoirs* for other modes of explanation.

I have already stated, that the most destructive kind of earthquake-shock is the *vorticose*, the reality of which seems to be attested by several very curious effects occasionally observed. One of these was seen after the celebrated earthquakes of Calabria, in the twisting of the two obelisks mentioned above†; and Mr. Mallet instances several cases of a similar description—as at Boston, in New England, in 1755; at Valparaiso in 1822; and at Conception in 1835; but conceives that the phænomenon may be referred to the same kind of motion as the two former, with this difference only, "that the centre of adherence between the ground and the base of the object moved was neither directly under the centre of gravity, nor in the plane of motion passing through its centre of gravity; but in some point of the base outside the line of its intersection by the plane; in which case the effect of the rectilinear motion in the plane of the base will be to twist the body round upon its bed, or to move it laterally, and twist it at the same time, thus converting the rectilinear into a curvilinear motion in space; the relative amount of the two compounded motions being dependent, upon the velocity and time of movement of the base, and upon the perpendicular distance measured horizontally at the surface of adherence between the centre of adherence, and the centre of gravity of the body."

This explanation however of the *nature* of an earthquake-shock leaves it quite open to us to assume any *cause* that may in our opinion accord with the other phænomena, as the Agent producing it. I shall therefore proceed in the next chapter to consider the concomitants of the shock, with the view of determining, how far they are referable to volcanic action, or are in accordance with those that usually attend upon an eruption.

* British Association Reports for 1847.

† Page 510.

CHAPTER XXXIII.

ON EARTHQUAKES.

THE CONCOMITANTS, EFFECTS, CAUSES, AND PHYSICAL CHANGES BROUGHT ABOUT BY THEM.—Flames and gases emitted during earthquakes.—Their influence upon the barometer.—Physical changes resulting from them—fissures in the earth—elevations and depressions of the land occasioned.—Connexion between earthquakes and volcanos—shown in the case of that of Lisbon—the Caraccas—the West Indies—Scotland.—Earthquakes do not arise from electricity—or from the falling-in of caverns. Their probable influence upon the structure of the globe—in elevating and submerging tracts of land, &c.

IN the last chapter our attention was principally directed to the *nature* of the shock experienced during earthquakes. In this my object will be, first, to consider their connexion with volcanos, and then to point out the probable influence they have exerted, or are likely to exert, upon the surface of the globe.

It may facilitate our understanding of the former department of our subject, if we point out in the first place certain other phænomena, which take place during any of these great natural convulsions, tending to illustrate rather the *cause* than the *character* of the shock.

Thus earthquakes are not unfrequently accompanied by the emission of flames and gases from the ground. Half an hour before that of 1797 at Cumana, a strong smell of sulphur was perceived on a hill where the subsequent agitation was strongest.

During the shocks, flames burst forth from the banks of the river Manzanares, and even from the water in the bay of Cariaco. In the mountains of Cumanaçoa, as well as in the Steppes of New Andalusia, flames frequently issue from the ground, flickering for hours on the same spot, and, as it has been asserted, (I know not how truly,) without burning the trees, or altering the nature of the soil *.

Similar observations were made at Lisbon during the earth-

* Humboldt, Pers. Narr. vol. ii.

quake of 1755, and at Jamaica a black cloud, which obscured the air, burst forth from fissures in the ground.

During the great earthquakes of the Abruzzi in 1702 and 1703, water and stones were projected in large quantities and to a great height from the ground near Aquila, a city which was laid in ruins by this catastrophe. Humboldt relates the same as happening also at Cumana, and Dolomieu in Calabria.

The shocks which took place in the valley of the Mississippi during the years 1811, 1812, and 1813, caused near New Madrid great fissures, from whence smoke and steam issued, and even flames are reported to have been observed proceeding from the same apertures *.

During the earthquake of 1828 at Cumana, an English vessel in the harbour was suddenly enveloped in mist, and a noise like that of distant thunder was heard. At the same time a shock was felt, and the surrounding water hissed as if a hot iron had been introduced in it, sending up a number of bubbles, accompanied by a smell of sulphur. Multitudes of dead fish floated on the surface †.

On weighing anchor, it was found that one of the chains which connected it with the vessel, lying on soft mud, had been melted, and the rings, which were two inches in diameter, had been stretched to the length of three or four inches, and become much thinner than before.

These gases and vapours may occasionally exert an influence upon the barometer, which does appear to be *indirectly* affected by some earthquakes. Their sensible properties also may occasion that uneasiness which animals are said to evince before any such event. Thus, according to the accounts of some writers, rats and mice leave their holes—alligators seek the dry land—quadrupeds snuff the ground, and manifest such signs of the impending calamity, that in countries where earthquakes are common, the inhabitants take the alarm in consequence, and escape from their houses ‡. It is right however to add, that more recent authorities dispute altogether the correctness of these statements.

* Consult Lyell's Principles, 5th edition.

† Férussac, Bull. tom. xvii.

‡ Poli gives a remarkable account of this in his Memoria nel Tremuoto di 26 Juglio 1805, p. 48.

I next proceed to the changes which earthquakes have brought about on the surface of the globe.

If we were to rely upon the accounts transmitted to us of earthquakes observed within recent periods, we might perhaps conclude that they affected the surface but slightly, and were chiefly influential in bringing about the destruction of the frail works of man.

Thus the most common effects narrated as arising from them are of the following description:—

The wavy nature of the shocks, which, as we have seen, is the one of most ordinary occurrence, occasions such a stretching of portions of the ground, as sometimes to split it asunder. Hence amongst the consequences resulting from it in the earth itself, fissures are the most frequent. Thousands of such rents occurred during the earthquake of Calabria, and at Catania, in 1818, the walls of the houses opened and then closed again in consequence. In the same district, these fissures generally follow some given direction, as in the Mississippi valley from S.W. to N.E.

Elevations and depressions of the land are phænomena less frequently recorded, but for instances of them we may refer to the earthquake of Lisbon, which caused the rise of a little creek, until that time always containing twelve feet of water, but now elevated above the sea-level.

In that of Calabria, some of the houses of the town of Terra-nuova were elevated above their former level, whilst others were depressed; and near Cossolito, Dolomieu relates that a house was heaved up several hundred feet without sustaining any damage.

In Lancerote, two pyramidal rocks of basalt were heaved up on the coast, after the volcanic eruption of an adjacent mountain *.

But the most authentic instance of upheaval, as a consequence of earthquakes, was that recorded by Miss Graham on the coast of Chili, where in 1822–23 a succession of shocks occurred, and where the whole coast for a length of twenty miles was elevated with the utmost regularity as much as three or four feet. Shells adhering to the rocks were just brought above the sea's level, and it was remarked

* Humboldt, Personal Narrative, vol. i.

that raised beaches, caused by similar convulsions, might be traced along the coast, at a height of fifty feet *above* the present level of the sea.

The changes produced by earthquakes in the neighbourhood of Cutch, although confined within a smaller compass, are even more remarkable; but these have been already detailed in the 21st chapter of this work.

I may also refer to the 12th chapter for the particulars concerning the temple of Serapis at Puzzuoli, which affords a remarkable example of the alternate sinking and rising of the coast; but I there omitted to state that, according to Mr. Smith of Jordan Hill, a second subsidence is taking place, for the observations he has made and collected lead him to suppose that the ground has now begun to sink a second time.

Other similar phænomena occur in various parts of the same coast, and in Sicily the occurrence of beds of shells, mostly of living species, at a considerable height above the sea, favours the same conclusion.

In short, there seems to be great reason for supposing, that earthquakes have on many occasions heaved up new tracts of land above the sea, as well as depressed others below its level.

We have lastly to consider the connexion between earthquakes and volcanos.

This is in the first place borne out by the occurrence of earthquakes, in the neighbourhood of volcanos, and as a prelude to their eruptions, the shocks increasing in violence until the mountain relieves itself by discharging its contents. This is generally observed at Vesuvius and Etna; and when the wreath of smoke disappears from the summits of Tunguragua and Cotopaxi, earthquakes are expected. Chimboraço also exhibits the same alternation of earthquakes and eruptions.

In some places indeed, where dreadful earthquakes have taken place, as at Lisbon, Calabria, the Caraccas, and the Mississippi valley, volcanos do not occur; but it is very natural that where a vent is wanting, volcanic action should give rise to earthquakes of the worst kind. It is remarkable that during that of Lisbon, Vesuvius exhibited a very uncommon appearance in the column of smoke proceeding from it. During the earthquake of Calabria, Stromboli, for the

first time within the memory of man, ceased to show signs of activity, and in Peru, the volcano of Pasto had at the beginning of 1797 emitted a dense black column of smoke, which having on the 1st of February ceased, was immediately followed by the terrible earthquake of Riobamba, in which 40,000 persons perished.

But the chain of connexion between earthquakes and volcanos is best shown by going through the series of events of this nature enumerated by Humboldt *, which took place in 1811 and 1812 in the Western world.

First, the island of Sabrina in the Azores rose suddenly from the sea from a depth of 120 feet, with violent earthquakes and a disengagement of smoke and flames. Soon after this severe shocks continued from May 1811 to April 1812, in the smaller West India islands, 800 miles distant, and especially at St. Vincent, that is, in the neighbourhood of one of the most active volcanos in that archipelago. The shocks extended to the continent of North America, where occurred the violent earthquakes of the valley of the Mississippi. During this time, in December 1811, an earthquake took place in the Caraccas, and in March 1812 occurred the terrible one which ruined that city, and continued till the 5th of April. At last, on the 30th of April 1812, the volcano of St. Vincent, which had been quiet since 1718, burst out with a tremendous explosion, and the shock extended to the Rio Apure, in the Steppes of Calabozo, at a distance of 210 miles. Thus ended this great concatenation of volcanic outbreaks and of earthquakes, the greater part of the events occurring on the coasts, and in the interior, of the Gulf of Mexico, which is included between the continents of North and South America.

Mr. Darwin has drawn up a similar series of facts connected with the earthquake of Conception in 1835 †.

On January 20th, 1834, a dreadful earthquake took place near the city of Pasto, lat. 1°·15 north, in which the town of Santiago was swallowed up. On May 22nd, Santa Martha, lat. 11°·30, was thrown down by an earthquake.

* Pers. Narr. vol. iv.

† See also Gemellaro on the Meteorological Phænomena of Mount Etna, extracted in the Journal of Science, vol. xiv.

September 7th, violent earthquakes occurred in Jamaica.

1835, January 20th, Osorno, lat. 40°·35; Aconcagua, lat. 32°·12 south; and Coseguina, in lat. 13° north, were simultaneously in a state of eruption.

February 12th, an earthquake was felt at sea, of great violence off the coast of Guiana.

February 20th, Juan Fernandez had a submarine eruption —Conception and the neighbouring towns were destroyed, and the coast permanently elevated. The volcanos along the whole length of the Cordillera of Chili were in eruption.

November 11th, severe earthquakes took place at Conception; and Osorno and Corcovado were in violent action.

December 5th, Osorno fell in with a grand explosion.

Now if the synchronous eruptions of Osorno, Aconcagua, and Coseguina are admitted to arise from the same cause, that cause must have simultaneously acted along a line of more than 2000 miles.

Lastly, the occurrence of eruptions in places where there are no true volcanos, during the continuance of earthquakes, may be regarded as the strongest proof of the connexion between the two.

Thus, during the earthquake of Lisbon, columns of smoke, as we have seen, burst forth from fissures in the ground; at Aquila in the Abruzzi, stones, water, smoke, flames, and sulphureous vapours were disengaged; and at Messina, flames.

In Eubœa, it is related by Strabo that earthquakes continued, till, in the Lelantine fields near Chalcis, the earth opened, and a stream of mud (or lava*) was emitted. During the earthquakes of the Caraccas torrents of water, and on the coast of Venezuela immense volumes of mud, called in the country *Moya*, filled valleys of 1000 feet in breadth to a depth of 600 feet. This *Moya* was a brownish-black mass, containing blocks of glassy felspar and pumice, ammonia, silica, alumina, lime, and a little oxide of iron, so that it constituted in fact a kind of volcanic tuff.

These facts may be sufficient in themselves to establish a connexion between earthquakes and volcanos, and the only question that can arise, relates to those feeble shocks, which

* Page 330.

manifest themselves in a few places apparently very remote from all indications of igneous action.

At Comrie, near Crieff in Perthshire, shocks have been very frequent during the last fifty years, and the earthquake of 1839 was felt there more strongly than in any other part of Scotland *. In 1841, it appears that one, capable of affecting the seismometer, occurred on the 26th of July, and another on the 30th, which split the walls and damaged the chimneys of houses. A pretty severe shock took place also on the 9th of September 1841; and again on the 8th of June 1842, when the seismometer indicated an upheaval of about a quarter of an inch †.

Slight earthquake-shocks have likewise been noticed in several parts of England, especially in Sussex, and in many other countries apart from all existing volcanic vents.

It must however be recollected, that Comrie lies not very far from the extinct volcanos of the Western Islands, and that in Sussex uplifted lines of hills exist, which seem to show that volcanic fires have been at work formerly in that part of the world.

In whatever way however we may deal with these few exceptional cases, the evidence seems complete as to a connexion subsisting between the more violent shocks, and those igneous processes which I have described in a former portion of this work.

The only other hypotheses indeed by which earthquakes have been accounted for, are, that of Stukeley, who refers them to subterranean discharges of electricity, and that of Buffon, who attributes them to the falling-in of caverns existing in the interior of the globe.

The arguments that have been from time to time adduced in favour of the electrical theory are vague and inconclusive: they are drawn from some fanciful analogy between the noise and shock accompanying lightning, and those which are experienced during an earthquake; from the extreme rapidity with which the motion is propagated; from the electrical state of the air both before and after an earthquake; and from

* See British Association Reports, vol. x. p. 49.

† Mr. David Milne's Report, do. vol. xi.; see also vols. xii. and xiii.

the sulphureous smell sometimes perceived, which is thought to resemble that produced by the electrical shock.

Electrical phænomena indeed are common during the continuance of volcanic eruptions, produced in all probability by the evolution of large quantities of steam and other elastic fluids, the decomposition and subsequent regeneration of water, and other processes that accompany these grand operations of nature.

Moreover, the late discoveries made with regard to the opposite electrical condition of mineral veins, and of the rocks containing them, may lead us to believe, that much remains to be learned with regard to the agency of this mysterious power in the interior of the earth; although it is not easy to persuade ourselves, that in the solid strata of the globe, consisting as it does of conductors, the same accumulation of electricity can ever take place, as that which produces the phænomena of thunder and lightning in the atmosphere.

Nor indeed are the facts observed of such a nature as to baffle our attempts at referring them to their more obvious cause, volcanic processes, more especially when we are reminded of the rapidity with which undulations are propagated through solid matter, as has been fully entered into in the last chapter, and as was illustrated by Gay-Lussac, by the shock produced by the head of a pin set to vibrate at one end of a long beam, which he found to be distinctly perceptible at the other.

With regard to the theory of Buffon, it may be sufficient to observe, that the existence of cavities in rocks can only be supposed to arise from one of two causes—something connected either with their original formation, as in the case of limestones, or with the convulsions that have subsequently affected them.

Now with regard to the *first*, it is highly improbable that any great sinking of hollows that have existed for so long a period should take place at the present day; and with respect to the *second*, the very existence of *such* hollows implies the previous exertion of volcanic agency, for we know of no other cause in nature competent to heave up rocks in the manner necessary to produce such cavities.

We seem then to be justified in the conclusion, that earthquakes arise from a peculiar exertion of the same force, some of the more manifest effects of which we have already traced, when describing the operations of volcanos.

We have also seen, that earthquakes have in various instances produced considerable changes in the configuration of the earth's surface, elevating certain portions of the land and depressing others, altering the course of rivers, producing deep fissures in the solid strata, and converting dry land into sea.

The preceding chapters, in which volcanic phænomena came before us, afforded incidentally various other instances of the same class of effects, which, to avoid needless repetition, are here omitted; but the changes thus noted are insignificant and unimportant, compared with those which analogy suggests as the probable effects of the same forces, operating during an immense period of time, and in a much greater number of localities.

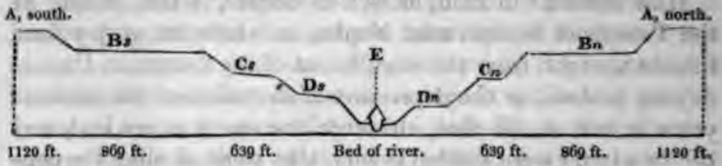
We have already (Chapter XXV.) pointed out the probability, that extensive areas of land in the Pacific Ocean are gradually subsiding; but this seems to imply, as a concomitant at least, if not as a cause, the elevation of other tracts of equal dimensions, and that such is really the case in South America has been lately shown by the important investigations of Mr. Darwin.

This distinguished naturalist, during the exploring expedition in which he accompanied Captain Fitzroy, had an opportunity of examining various portions of the eastern coast of South America, from the Rio de la Plata to the Straits of Magellan, and likewise a considerable part of the western coast as far north as Lima, in both of which tracts he found reason to conclude, that the coast had been raised, for a distance of at least 1180 miles, to a height of 100 feet in the province of La Plata, and of 400 feet in Patagonia.

In many places however the elevation had been much more considerable, there being in Patagonia a succession of raised beaches, severally 350, 200, and 80 feet above the sea, the steep escarpments dividing the several beaches being due to the action of the waves during the period at which the process was proceeding. The terraces are all covered with

rolled pebbles, intermixed with which are shells belonging to existing species; so that these discoveries appear, as it were, to supply the connecting link between the every-day operations of earthquakes, and processes which have been instrumental in upheaving the solid fabric of our continents.

North and South Section across the Terraces bounding the valley of the River San Cruz, high up its course.



The height of each terrace above the level of the river is shown by the number under it. Horizontal distance much contracted. (Darwin, South America, p. 10.)

On the western coast evidences of upheaval were observed at the island of Chiloe, at Conception, at Valparaiso, at Coquimbo, and at Callao, the port of Lima; and this upward movement would seem to have occurred at intervals, and in some parts almost continuously, from lat. 45°·35 to 12° south, a distance of not less than 2075 miles. The upheaval seems to have amounted, at Chiloe to 350 feet; at Conception certainly to 625, and by estimation to 1000 feet; at Valparaiso to 1300 feet; at Coquimbo to 150 feet; but at Lima only to 85 feet since the period at which the country was inhabited by the Aborigines—remains of human art having been met with on the raised terrace at that elevation.

Now that this upward movement has in some cases been due to earthquakes, does not admit of doubt. The island of St. Mary's, near Conception, for instance, was elevated eight, nine, and ten feet during the great earthquake of 1835, and Valparaiso about three feet during that of 1822.

In these cases the upheaval was sudden; but Mr. Darwin contends, in opposition to the opinion of his great rival observer, M. D'Orbigny, that the coast of Patagonia at least has been brought to its present level by a very slow and gradual movement, which was continued during a succession of ages, though interrupted by occasional pauses, and even alternating with subsidences.

Such an inference however by no means precludes the notion, that the Agent may in this instance have been essentially the same as in the former.

The more indeed one considers those phænomena, which are confessedly connected with volcanos, the more reason one finds for believing, that gradual as well as sudden alternations of level have equally resulted from their operations.

How different in kind, as well as degree, is the sinking of the Temple of Serapis near Naples, in which the very pillars remain upright, from the engulfment of the mountain Papandayang in Java, or the depression of the valley of the Jordan! yet who will doubt that, although the one was gradual, and the two latter were sudden events, they were all alike the consequences of volcanos? So likewise the upheaval of the coast of Chili, which seems to have resulted from a gradual movement, may have arisen from a modification of the same cause as the elevation of the Puy de Dôme, or of Jorullo, both which must have been sudden and violent operations.

And in like manner, the elevation of the land in Scandinavia and in Chili may be referable to the same volcanic agency, although the former goes on silently, imperceptibly, without the intervention of any earthquake-shocks, and far remote from any appearances of volcanos; whereas the other is not only attended with earthquakes, but may also be conjectured to have been at certain epochs brought about by a sudden and violent upheaval, from the boulders which overspread the continent, and which, according to Mr. Hopkins, have been distributed over the face of the country by a *wave of translation*, caused by the rising of a large mass of land from the bosom of the ocean.

But in alluding to these latter subjects, I feel myself entering upon speculations which, if indulged in, would soon carry me beyond the limits prescribed for this Treatise, in which my endeavour has been, rather to collect together materials for a future Theory of the Earth, than to construct one myself.

I will leave it therefore for the geologists of another age to explain, why the upheaval of continents should take place gradually in one part of the globe, and by starts in another;

only remarking, that as we have examples of both these movements in countries subject to earthquakes, and beset with volcanos, it seems more philosophical to attribute the gradual elevation of continents in all cases to volcanic action, than to assume the existence of two independent causes to explain operations differing only in these subordinate particulars *.

* See however the remarks of Darwin, Lyell, and others on this point. I would observe that Mr. Darwin, although inclined to attribute the elevation of mountain-chains generally to a slow and gradual movement, does not appear prepared to deny the reality of paroxysmal elevations. See Geol. Trans. vol. v. p. 624.

CHAPTER XXXIV.

THERMAL SPRINGS—THEIR GEOLOGICAL POSITION.

SALSES OR MUD-VOLCANOS—improperly designated by the latter name—not being amongst the primary effects referable to the action of volcanic forces.

THERMAL SPRINGS—afford indications of languid volcanic action.—This proved by their immediate connexion with volcanos—active—or extinct—or where not so circumstanced, by being placed at the foot, or in the midst, of some chain of mountains that has been elevated.—Instances of the latter in the Pyrenees—in the Alps.—Where not connected with any great system of mountains, they often proceed from rocks which show evidences of dislocation.—Examples of this, in the thermal springs of Bristol—of Matlock—of Carlsbad—of St. Paul near Carcassone—of Pfeffers—in those of Virginia, &c.

IN the two preceding chapters I considered a class of phænomena which seem to be connected with volcanic operations whilst in a condition of intense activity; I next proceed to those indications of their existence which can be discovered when they are in a state of apparent quiescence, or when the processes that occasion them are going on in a slow and languid manner.

But before entering upon this extensive subject, it may be right to make a few remarks upon a class of phænomena, which, from the name of *mud-volcanos* frequently assigned to them, may be assumed to have some connexion with the Agent under consideration.

As they are seen only in a very low degree of development in the only volcanic region with which those geologists, whose researches have been circumscribed within the confines of Europe, can be familiar, their real nature seems to be involved in much uncertainty.

In the chapter on Sicily I have related the appearances that present themselves at Macaluba, which I can only regard as secondary effects of volcanic agency, originating in local accumulations of materials which may have been brought

together perhaps by the operation of volcanos, but do not proceed directly from so deeply-seated a cause.

The mud-eruptions of South America, described by Humboldt, have clearly no connexion with such phænomena as these, so that for this as well as for other reasons, the name *mud-volcano* should be discarded, and that of *salses*, by which they are also known, adhered to.

That they are in certain parts of the globe important geological agents, will not be disputed after the statement given in my 21st chapter of the physical changes produced by their operation in the Crimea, the Black Sea, and the Caspian.

But to ascribe them to the same cause as volcanos would be obviously premature,—at least until some attempt shall have been made to explain, why many of their phænomena are so entirely distinct from those proceeding from the former.

True volcanos, as we have seen, generate sulphuretted hydrogen and muriatic acid, upheave tracts of land, and emit streams of melted felspathic materials. Salses, on the contrary, disengage little else but carburetted hydrogen, together with bitumen and other products of the distillation of coal, and pour forth no other torrents, except of mud, or argillaceous materials mixed up with water.

It is nevertheless far from improbable, from the extensive scale in which they appear to be developed in the regions explored by Sir Roderick Murchison, M. de Verneuil, and Dubois de Montpereux, that the reports which have been circulated respecting the existence of burning mountains in Central Asia, and other regions remote from the sea, which in other cases seems an essential condition to the putting forth of genuine volcanic forces, may have originated in this class of phænomena.

Such, as we have seen, is the opinion of one of the individuals most conversant with the physical structure of these remote and little-known regions of the earth—I mean the traveller and geologist Erman; and with his authority on the other side, no one in the present state of our knowledge can be justified, either in building a theory of volcanos on facts derived from so apocryphal a source as that of Chinese or

Indian writers, or in alleging the latter as objections to a theory based upon the concurrent evidence of those naturalists who have explored parts of the globe more open to investigation.

Whilst therefore I would recommend the subject of Salses to the consideration of my readers, and would refer them to this work for a summary of what is known concerning their history, I forbear to bring them forward in the present department of this volume, as furnishing facts that can be safely relied upon in illustration of the *primary* phænomena of volcanos.

Of the effects then resulting from a more tranquil and subdued action of the forces we are considering, the most remarkable are Thermal Waters, or natural Springs possessing a temperature exceeding that which would be imparted to them by the mean of the climate in the country in which they occur. But here it will be necessary to pause, in order in the first place to inquire, whether every minute excess of temperature beyond that point is sufficient to make a spring rank as thermal.

Gustavus Bischoff* indeed asserts, that all springs of constant temperature are somewhat warmer than the mean of the climate, and according to Humboldt, this excess of temperature in springs increases with the latitude; in Paris, lat. 48°·50, the mean temperature of the climate being 51°·6, that of the springs 52°·7—excess 1·1; at Berlin, lat. 52°·31, the atmospheric temperature being 46°·4, terrestrial 50°·2—excess 3°·8, indicating a rate of progression equal to about 0·7 of a degree of temperature for 1° of latitude. But, on the other hand, the accurate observations of Playfair have shown, that at Edinburgh, in a still higher latitude than either, namely 55°·58, the temperature of the springs is identical with that of the atmosphere; so that this supposed progression, if it exists at all, would seem to be at least limited to still higher latitudes even than the latter locality.

* See his valuable memoirs on the Laws of Temperature (*Wärmelehre*), contained in the Edinb. New Phil. Journ. for 1836, but now published a a separate volume.

Neither are the observations of Wahlenberg on the Scandinavian peninsula*, nor those of Kupffer on the Ural range†, absolutely conclusive as to the generality of the supposed law, even in those still higher latitudes to which they respectively refer.

The elevation of temperature which these writers show to exist, may, for aught we know, be confined to the neighbourhood of uplifted chains of mountains; it may be the consequence of those great natural events to which are owing the disturbances there experienced, and consequently it may not extend to the great plains of Russia or Siberia, where no such local influences manifest themselves.

It may however be said, that the high temperature which is proved to pervade the interior of the earth, and which, judging by the very limited range of human observations, would seem to go on progressively increasing, sufficiently explains the temperature of springs, which will always exceed that of the external air in a greater or lesser ratio according to the depth from which they have arisen.

According to the view thus taken, all springs that possess a constant temperature must have been derived from a point where the heat is permanently greater than on the surface, and the only reason why one spring is hotter than another will be, that it has proceeded from a greater depth within the earth.

These two propositions however ought to be kept distinct, as the first does not imply the second; and whilst I am disposed to concede, that the higher temperature of the interior of the earth may sufficiently account for the law which Kupffer and Humboldt have attempted to establish, supposing it to be substantiated by subsequent observations, I should protest against the latter conclusion, on grounds connected with the phænomena of thermal waters which will be afterwards discussed. Hence, removing from the class of "thermal" all those springs whose temperature exceeds by no more than a few degrees that of the atmosphere, I shall proceed to consider such only as exhibit some marked or abnormal elevation above that standard; and where this occurs, inquire

* Annals of Philosophy, vol. iv.

† Edinb. New Phil. Journ. vol. xxii.

whether there be anything in the nature of the phænomena they exhibit, or in the character of the rocks surrounding them, that may lead to the suspicion of volcanic agency being felt in the country round about.

Now if we take a survey of the various localities in which hot springs occur, we shall find that a very large proportion of them arise from rocks, which in their general aspect and structure attest the operation of volcanic forces, at one period or at another.

Thus there is scarcely any volcanic district known in which hot springs do not abound; we find them alike, on the slope of Vesuvius, and at the foot of the Monte Nuovo near Naples, at Mount Etna, in Iceland, and amongst the volcanos of the New World. The connexion between the heat of the springs and the action of the volcano is in these cases perhaps sufficiently apparent; but the most conclusive instance of the kind was furnished by the event which occurred in Mexico in the year 1759, when the volcano of Jorullo was suddenly heaved up in the course of a single night, and the waters of two rivers were engulfed in the abyss thereby occasioned. The rivers in this case disappeared, but in their place there rose out of the ground several thermal springs*,—a plain proof that the water, which entered the recesses of the rock, had derived an increased temperature from the volcanic operations there carried on.

Indeed, without pausing to enumerate the principal localities in which thermal waters occur in connexion with volcanos, of which indeed, so far as relates to Europe and some parts of America, a list is given in the annexed Table, I may refer my readers to the foregoing chapters, in which it will be seen that almost every region described has its own system of thermal waters associated with it.

Other thermal waters are situated in the midst of volcanos which are considered as extinct—that is, which have given no indications of activity since the country was first inhabited; such are those of Vichy, Mont Dor, and Chaudesaigues in

* See Chapter XXX.

Auvergne, of Glasshütte and Pesth in Hungary, of Töplitz in Bohemia, and of Battaglia among the Euganean Hills. In these cases, it can hardly be doubted, that the cause of the temperature of the springs is intimately connected with the volcanic operations which have at one time occurred, or which may be now taking place in a more suppressed form, somewhere in the neighbourhood.

It is remarkable that the temperature of this class of springs is for the most part lower than that of springs in connexion with active volcanos, in which latter it sometimes falls but little short of the boiling-point. Such is the case with the spring called the Baths of Nero near Naples, with those of New Zealand, of Peru, &c.; and the Geysers of Iceland, as we have seen, even exceed that point, at the bottom of the canal or reservoir from which the water and steam ascend.

On the other hand, Bourboule, the hottest spring near the extinct volcanos of Auvergne, does not exceed 121°; in the Eifel, that of Bertrich is 90°; in Hungary, that of Glasshütte, 129°, and that of Buda, 132°.

These are the hottest springs connected with extinct volcanos that I am acquainted with in Europe.

But there is also a very large proportion of thermal waters which appear to lie quite remote from volcanos either active or extinct, and hence it becomes necessary to inquire, what the situations may be in which these are principally found.

Now it so happens that a great number of these are met with either at the foot, or else embosomed in the midst, of some elevated chain of mountains. Thus on the northern declivity of the Pyrenees we meet with a succession of hot springs, corresponding nearly with the direction from west to east, in which the chain itself extends*.

Professor Forbes† and others have likewise shown, that in the majority of these cases the springs have gushed out at or near to the line of junction between the granite or other igneous products, and the stratified rock resting upon its flanks, which from its highly inclined position would seem to have been upheaved; whilst in a few cases where they occur

* For a list of these see the table at the end of chapter xxxv.

† Phil. Trans. 1836.

in the midst of the granite itself, patches of stratified rock are found contiguous.

Thus the same agent which forced up the granite through the axis of the chain, may have given rise to the hot springs which accompany it just along the line of disruption.

The following are the details by which this principle is established:—

Hot springs gush out just at the boundary of granite with a stratified rock at

Northern boundary.	Eaux Chaudes. Cauteretz. Bagnères de Luchon. Lez, in Spain. Aulus. Ax.	Escaldas. Dorres. Arles.	Southern boundary.

In stratified rocks closely dependent upon granitic rocks which show evidence of dislocation—

Eaux Bonnes.	Barèges.
Bagnères de Bigorre.	Caudiac.
St. Sauveur.	Ussat.

In the heart of a granitic chain, but with a patch of stratified formations near.

Western extremity.	Olette. Thuez.	Vernet ? Molitg ?	Eastern extremity.

The details given below, resting on the authority of Professor J. Forbes, seem to justify this classification of the thermal waters of the Pyrenees.

Eaux Chaudes.

Limestone runs towards the granite, and is vertically elevated by it. Hot spring just at the junction. Valley one of disruption.

Eaux Bonnes.

Spring rises from limestone, but granite is found at no great distance.

Cauteretz.

Near it are highly-inclined strata of clay-slate, which at Cauteretz contain much hornblende. Granite rises in vast masses to the southward, and its point of junction with the slate separates two distinct groups of hot springs.

as at St. Sauveur.

BAGNÈRES DE BIGORRE.

In limestone, but an outbreak of granite occurs near it.

CAUDIAC.

In limestone with patches of granite.

BAGNÈRES DE LUCHON.

In granite near its junction with slate.

LEZ, VALLÉE D'ARAN, IN SPAIN.

Near the boundary of a patch of granite.

AULUS.

Exactly at the junction of granite and stratified rocks.

USSAT, NEAR TARASCON.

In limestone, rocks very precipitous, with granite near it.

AX.

Here the granite forms a sort of centre of elevation, from which the country slopes in three directions, east, north, and south. Hot springs gush out very abundantly all around.

ESCALDAS AND DORRES.

Springs rise from granite, as usual near its junction with slate.

THUEZ.

In the Alps also the numerous thermal waters of Dauphiny Savoy, Valais, and Upper Piedmont, lie partly in the primary rocks of the central chain itself, but in greater numbers at their margin, on the boundary of the primary and secondary formations, where the strata give indications of having been torn by some violent convulsion. All along the southern declivity of the Alps, a continued chain of hot springs emerges from the line of junction of the primitive with the newer rocks, which can be traced from the foot of Mont Blanc and the Great St. Bernard, to the volcanic products of the Euganean Hills, in which line are found the thermal waters of St. Didier, Acqui, Pelegrino, Bormio, Masimo, Caldiero, Abano, Battaglia, and Monte Ortoni.

But independently of the general presumption which may be entertained, that thermal waters occurring in the immediate vicinity of chains of mountains owe their temperature to the same volcanic cause by which the elevation of the range had been brought about, there are certain peculiarities of position in each instance which tend in general to strengthen the same conclusion.

I have already stated, that in the Pyrenees they approximate in most cases to the line of junction between the intrusive and the sedimentary rocks—the motive force, and the mass moved,—whilst in many they are found near the axis of the chain, in some valley penetrating deeply into the interior of the rocks of which the ridge is composed.

Thus M. De la Rive, sen., has observed *, that in the Alps the hot baths of St. Gervais are situated exactly on the spot which, of all others, combines most completely the conditions of approaching in the nearest degree to the centre of the chain, and being at the same time least elevated above the level of the ocean.

In many cases, as in the valley of Mont Dor, the fissure itself would appear to have been caused by a disruption of the rocks consequent upon the upheaval of the chain, and at any rate the position is one which brings them into nearer proximity to the supposed cause of the heat. Such too is the case at Barèges, Cauteretz, and St. Sauveur, in the Pyrenees.

* Bibliothèque Britannique.

It is remarkable, that the hot spring of Aix in Provence gushes out just about the point, at which the line of elevation belonging to the Pyrenees would be intersected by another line that should represent the elevation of the Dauphiny Alps, a position in which the chances of volcanic agency manifesting itself are of course doubled.

But here another circumstance may be pointed out which adds greatly to the probability that their origin is of a volcanic nature—I mean the contiguity of these springs to some remarkable dislocations of the strata, which have been pointed out by Sir R. Murchison and Mr. Lyell in their Memoir on the Freshwater Formations of this district*.

Now the same inference had been already deduced by myself with reference to several of the thermal waters of Roussillon which I examined in the summer of 1830†.

In several cases, as at Alette, Rennes, and Campagne, a change of dip seemed to occur just where the springs burst out, coupled, in the case of Alette, with the fact of the gorge, through which the river Aude passes just before it reaches the locality of the spring, being highly abrupt, and placed at right angles to the general direction of the valleys contiguous, —circumstances which, taken together, suggest the idea of violent action having occurred in the vicinity of that spring.

At St. Paul de Fenouilhadès, on the road from Carcassone to Perpignan, near the town of Caudiès, a warm spring, having the temperature of 22° R., gushes out from the bottom of a vertical cleft or fissure in the range of hills which bound the valley to the west.

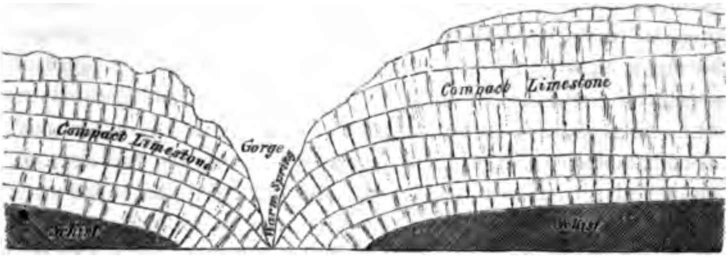
* Edinb. New Phil. Journ. No. 21.

† These views were first brought before the public in a paper read before the Société d'Hist. Nat. of Geneva in 1830, and inserted in Boué's Journal de Géologie, and in a Memoir "on Thermal Springs and their connexion with volcanos" contained in the Edin. New Phil. Journ. for Dec. 1831. A slight sketch of them had however been previously introduced into an article on mineral waters contributed by the author in 1829 to the 'London Review,' a periodical which never reached a third number, although it might have been expected, that the support which it received from such men as Archbishop Whately, Mr. Blanco White, Mr. Newman, and Mr. Senior, whose names stand confessedly at the head of their respective parties or schools, would have secured to it a less ephemeral existence.

It is evident, both from the extreme narrowness and depth of this cleft, that water has not occasioned it, and the appearance of the rocks on either side shows that they have been acted upon by violence.

At a little distance both to the north and south of the spot at which the cleft occurs, the limestone rock capping the ridge pursues an almost horizontal course, and a series of schistous strata, consisting of gritstones and marls, is seen underneath it, occupying nearly the same level for a considerable extent.

But the calcareous rock just mentioned, when it approaches the cleft on either side, suddenly sinks downwards so far, that the subjacent schists in consequence altogether disappear, and the limestone is brought down to the lowest level of the valley; thus demonstrating that the formation of the fissure was accompanied by a very considerable dislocation of the strata in which it occurs.



Section at St. Paul de Fenouilhadès, Département des Pyrénées Orient.

The presence of volcanic action on both sides of the chain may likewise be inferred from the extinct volcanos of Ollot in Catalonia, on the Spanish side; and from those that occur at Agde, near Montpellier, and various parts of the Cevennes, on the French.

Earthquakes also, according to M. Palassou*, are frequent in all parts of this chain, although most destructive on the Spanish side, where, it is to be observed, hot springs are rare.

Nevertheless, even at Bagnères de Bigorre, several houses were thrown down by one that occurred in 1660, at which time the hot springs became suddenly cold.

* Nouvelles Mémoires pour servir à l'histoire naturelle des Pyrénées.

It has been remarked, that the earthquake which was experienced on the 25th May 1750 had for its central point the neighbourhood of the Pyrenees; for nowhere were its shocks so violent, or the damage occasioned by it so considerable, as in that chain, especially in the valley of Lavedar. The village, in which occurs the thermal spring called *Eaux Chaudes*, seems particularly exposed to this visitation. In the case of the most recent of these earthquakes, that of the 22nd of May 1814, it has been remarked, that the direction of the shock was nearly parallel to that of the chain itself.

In many instances where the *general* aspect of the country does not so forcibly impress upon the mind the idea of volcanic forces having been in active operation, there is something in the *particular* circumstances of the locality indicative of the same kind of agency.

Thus in our own country the tepid spring of St. Vincent's Rocks, underneath Clifton, gushes out of a fissure, which, whether we consider its extreme narrowness, and the abruptness of the cliffs that bound it on either side, or the hardness of the rock which composes its structure, cannot be imagined due to the action of running water, but must be set down as the effect of some convulsion of nature. It is evident indeed, that the river Avon, so far from having occasioned the channel in which it now flows, must have taken quite a different direction if the gorge had not already existed, for the waters would have found their way into the sea through the low country of Nailsea and Long Ashton, rather than have cut for themselves a course through the limestone rocks, which extend from Clifton nearly to the point where the river now discharges itself into the Severn.

But this is not all; for a geological examination of the rocks, of which a section is displayed on the right bank of the Avon, has brought to light evidences of great disturbance*. The regular succession of rocks appears to be as follows, beginning from below upwards:—

1. Limestone, thick beds.
2. Grit.
3. Shale.

* See a Memoir in the Geol. Transactions, vol. i. new series, by Dr. Buckland and the Rev. W. Conybeare.

4. Grit.
5. Millstone grit, all highly inclined.
6. Dolomitic limestone in horizontal strata.

But a little beyond the projecting mass of rock from which the new Suspension-bridge is to proceed, and where the Observatory is situated, a great fault has taken place, which has thrown down the limestone beds 120 feet, nearly to the level of the Avon, and thus brought into view the millstone grit which rests upon it; whilst a portion of the horizontal beds of dolomite actually seems to underlie the principal mass of limestone, owing to the great depression which the latter has undergone.

Connecting the occurrence of a warm spring with the above circumstances, we can hardly avoid suspecting, that the volcanic force which probably tore asunder the rocks may likewise have communicated to the spring its higher temperature.

The spot in Great Britain which most resembles St. Vincent's Rocks, in point of physical structure and position, is Matlock, where a tepid spring also occurs; and here too there is decided evidence of the rocks having been torn asunder by some convulsion of nature, both from the abruptness of the cliffs which bound the defile on either side, and from the existence of an enormous fault, much of the same description as that of Clifton*. It would be tedious to go in detail through the whole series of warm springs found in this country; but I may remark, that the volcanic rocks which are found in many parts of Derbyshire afford an additional presumption that the tepid waters of that county owe their origin to volcanic heat.

On the continent, one of the most decisive examples of the connexion between warm springs and disturbances in the strata is afforded by the celebrated mineral waters of Carlsbad.

These are described as lying at the bottom of a narrow valley surrounded by precipitous granitic rocks; but the

* See Whitehurst's Theory of the Earth; but we may hope shortly to obtain some more accurate details from Professor John Phillips, who has been engaged in examining the district.

lower part of the valley is formed of a kind of conglomerate, composed of broken masses of granite united together by a siliceous cement. It is probable therefore that these fragments may have been broken off at the time, when owing to some earthquake, or other physical convulsion, the rocks were riven asunder, and the valley itself was formed; a conclusion favoured by the fact, that none of the neighbouring valleys lie in the same direction, or have the same precipitous character.

A little river indeed is made to take a different direction, and to run at right angles to its original course by the occurrence of this defile, just as is the case with the Avon near Bristol.

The whole of the superficies of the valley is covered over by a calcareous deposit derived from the waters, which hold a large portion of carbonate of lime in solution, and it seems not improbable that at an earlier period, when the volcanic action was more intense, the spring may, like those of Iceland, have contained much siliceous earth, by the aid of which it was enabled to cement together the blocks of granite, and thus to form the conglomerate which is now found underlying the calcareous tuff*.

At Pfeffers, in the Grisons, a hot spring bursts forth from the side of an extraordinary chasm in a limestone rock, down which the waters of the river Tamina precipitate themselves. So perpendicular are the rocks composing the sides of this chasm, that it is the custom to lower provisions from the summit of the cliffs to the Bath House, which lies at the bottom, by means of ropes; and so narrow is the cleft that divides them, that a bridge of rock in one part actually extends across, and connects the two sides. The hot spring gushes out of a cavern very near the bottom of the chasm, and is reached by a rather perilous ascent along a narrow plank overhanging the ravine.

Now that a great change has taken place in the physical structure of the country near Pfeffers, would seem from the fact, for which I may quote the authority of Ebel, that the

* See a Memoir by Von Hoff, entitled Geognostische Bemerkungen über Karlsbad. Gotha, 1825.

Rhine, instead of flowing as it now does, almost due north to the lake of Constance, was at one time deflected to the east, in the direction of the lake of Wallenstadt, owing to the barrier that originally existed at the pass of St. Lucie, where the mountains present the appearance of having been riven asunder by some subsequent violence. For the evidence in support of this I must refer to M. Ebel's work*.

The other thermal springs in Switzerland appear under circumstances for the most part similar. Those at Weissenburg, in the canton of Berne, rise out of a gorge of the same kind as that of Pfeffers; those of Loueche appear at the foot of the mural precipice of the Gemmi, in the midst of indications of great confusion; whilst the springs of Baden, in the canton of Argovie, from which that of Schinznach is not far removed, lie near the point where, in consequence of the two mountains of Staffelegg and Lagern having been severed asunder by some great convulsion, the waters of the Rhine and of the other rivers which appear to have constituted a single lake, extending from Coire in the Grisons to this mountain ridge, including the lakes of Zurich and Wallenstadt, with the intermediate country, in one continuous sheet of water, flowed off by the channel now taken by one of the rivers, the Limmat, alone. Thus the Rhine may be supposed to owe its original direction to the event which produced one hot spring, and its present course to that which occasioned another.

The springs of Loueche or Leuk, in the Valais, are situated in a deep and precipitous valley very near the foot of the Gemmi. They rise from limestone, but not a very great distance from the vast granitic chain which extends by the upper parts of the valley of Lauterbrunner to the Jungfrau. The evidence of disruption on a great scale in the valley is almost as clear (Professor Forbes says) as such evidence can be. It is surrounded by mural precipices of singular boldness†.

The situation of the thermal waters in the beautiful moun-

* Manuel du Voyageur en Suisse.

† Forbes, Temperature and Geological Relations of certain Hot Springs, Phil. Trans. for 1836.

tain region of Virginia, west of the Blue Ridge, which I visited in 1838, strongly corroborates the views above enunciated.

Several of the most noted indeed of the mineral waters resorted to in this country for their reputed medicinal virtues, seem to be only slightly thermal, and to derive their efficacy chiefly from the sulphuretted hydrogen with which they are impregnated; such are the White, the Red, the Blue, and the Salt Sulphur Springs.

The three former acquire their distinctive appellation from their colour, the difference in which is probably attributable to that of the confervæ that grow on them, and impart their respective hues to the water; the latter, designated as the Salt, owes its name to the presence in it of a larger proportion of common salt than in the rest*.

One, "the Sweet Spring," is strongly acidulous, and slightly thermal; but two, which appear to possess no remarkable mineral impregnation, are designated by the names of the Warm, and the Hot Spring, from the more or less considerable elevation of temperature which belongs to them.

The Warm Spring I found to possess a heat of 96° Fahr., and the Hot Spring one of 102°, whereas the mean of the climate seems to be only about 56°†.

Now both these springs lie at a distance of about three miles one from the other, in a valley, the direction of which is nearly north and south; whilst it may be seen, by reference to the section which Prof. William Rogers has appended to his 'Geological Report of the State of Virginia,' 1836‡, that they are situated exactly at the anticlinal axis of the chain.

And on examining the rocks on either side of these springs, wherever the nature of the country allowed of my exploring them, I found every reason to place reliance upon the correct-

* The situation of these and other thermal springs in the United States is expressed in the Map at the end of the volume.

† See a Sketch of the Geology of North America by the author, published by the Ashmolean Society.

‡ And to his Memoir "on the Connexion of Thermal Waters in Virginia with Anticlinal Axes and Faults."

ness of his representations. To the west of the Hot Spring, the most southern of the two thermal waters referred to, the rocks become more and more inclined towards the west, as they approach nearer to it, until at length in its immediate vicinity they assume an almost vertical position.

Immediately surrounding the spring, which issues from the bottom of the valley, are vertical beds of a blue fossiliferous limestone, the lowest but one of the rocks incumbent on those of the Blue Ridge which are included in his series.

A very compact sandstone, used as a freestone, succeeds, then beds of clayslate again, and afterwards a highly ferruginous sandstone. Up to this point, the rocks are inclined at so high an angle, that they may be regarded as vertical, and in consequence of being so near the axis of the movement, they are often contorted and much disturbed.

Farther to the west, however, they are succeeded by strata of sandstone conglomerate, ironstone, and clayslate, dipping at a gradually decreasing angle of inclination, and this continues to be the case until they become nearly horizontal.

To the east of this spring, the density of the forests is such as rendered it impossible for me to obtain any knowledge of the mineral structure of the subjacent rocks; but this desideratum was supplied by following the road running to the east of the Warm Spring, which, as I have already stated, lies in the same valley.

Here, as we ascend the so-called Warm Spring Mountain, we observe the same rocks successively presented to us which we had seen to the west of the Hot Spring, and these —equally vertical in the immediate neighbourhood of the spring—dipping in the reverse direction, and at a high angle, farther to the west—and at length subsiding to a moderate inclination at a still greater distance from the axis of elevation. Professor Rogers supplies similar facts with respect to the other thermal waters of the district:—thus the Sweet Springs, he says, flow out from the nearly vertical, and inverted limestone near the centre of the valley; the Red Springs and Snake Run Group from points nearer to the junction of this rock with Formation III. of the Little Mountain. The axis in which the White Sulphur Springs arise, and that of the

Thermal of Brown's Mountain, are nearly, though not exactly, in the same line.

In short, out of 56 springs more or less thermal, 46 are situated on, or adjacent to, anticlinal axes; 7 on or near lines of fault and inversion; and 3, the only group of this kind yet known in Virginia, close to the point of junction of the Appalachian with the Hypogene rocks.

CHAPTER XXXV.

THERMAL WATERS, THEIR GASEOUS IMPREGNATION, ETC.

Gases evolved from thermal waters.—Nitrogen—at Bath, its quantity —Buxton, &c.—Cardiff—Clifton—Pyrenees—Alps—Ceylon—United States.—Sulphuretted hydrogen.—Carbonic acid.—Petrifying springs.—Valleys of elevation emitting carbonic acid.—Permanency of physical and chemical properties belonging to thermal waters.—Conclusions deduced from these premises as to the connexion between thermal waters and volcanos.—Tabular view of the properties and temperature of the best-known thermal waters.

In the last chapter I gave many examples of thermal waters which make their appearance where there is evidence of some convulsive force having been exerted on or near the spot from which they have burst forth, and in conformity to the established notions on the subject, regarded the force so manifested as a result of those processes in which volcanos, earthquakes, and other allied phænomena originate. Hence I concluded that thermal springs, even when at a distance from volcanos now in action, may be regarded as proceeding from causes of the same description.

And although it may be truly said, that springs of all temperatures are wont to appear where there are fissures or dislocations of the strata, yet those who have examined the spots alluded to in the foregoing chapter as giving birth to thermal waters will admit, that the chasms and disturbances of the strata which are found where they occur, are on a larger scale, and imply a more than ordinary exertion of eruptive force.

But inasmuch as it may be alleged, that a high temperature might be imparted to the water in these instances, owing simply to the depth from which it took its rise, just as has happened in the noted case of the Artesian well of Grenelle near Paris, I will next proceed to show, that natural thermal springs are in general accompanied by the same gases which volcanos commonly emit.

These may either rise in bubbles, owing to their escape

through the same channel by which the spring itself finds its way upwards, or if they have an affinity for water, may be held in chemical solution by it.

Of those gases which escape in bubbles, that most generally detected appears to be Nitrogen.

Aware of the interest attaching to the presence of this element, as illustrative of the theory of hot-springs and their connected phænomena, I have searched for it in all the thermal waters examined by myself in different parts of the world, and have detected it in so many instances, that coupling my own observations with those of others who have undertaken the same investigation, I am now inclined to regard nitrogen gas almost in the light of a constant concomitant of springs partaking of a high temperature.

The most abundant evolution of it I have ever witnessed was at Bath, where I was induced in the year 1833 to measure for a month consecutively the quantity each day evolved*. This I found to vary from time to time in a manner not easily accountable, but upon an average it appeared to amount to not less than 222 cubic feet daily from the King's Bath alone, and from the thermal waters of the place taken collectively, probably to not less than 250 cubic feet.

The gas was nearly pure, ninety-seven per cent. being nitrogen, three oxygen, besides a small but variable amount of carbonic acid.

This gas is also evolved in considerable quantities from a great number of other thermal waters.

Thus, for example, in this country, Dr. Pearson had many years ago detected bubbles of nitrogen issuing from the warm spring of Buxton; and from some observations made by myself at this spring, I am led to conclude that the quantity disengaged is about fifty cubic inches per minute. I have likewise discovered nitrogen in one or two other slightly thermal waters in the same county, as at Bakewell and at Stony Middleton.

I found it also in a tepid spring in South Wales near Cardiff, called Taafe's Well, a water possessing some reputation in the neighbourhood, and maintaining a temperature of 70° all the

* See my Memoir "on the Bath Waters," in the Philosophical Transactions for 1833.

year round. The quantity of gas is however here much smaller than at Bath, amounting to no more than about twenty-two cubic inches each minute.

There can be no doubt that the same gas is disengaged in connexion with the tepid waters of Clifton, for in the winter of 1834, when, owing to the continuance of wet weather, two other tepid springs gushed out from the bottom of the rock over which the new chain-bridge connecting the two sides of the chasm is to be suspended, I detected bubbles of gas which proved to consist of nitrogen 92, oxygen and carbonic acid 8 per cent. It would appear therefore that certain processes are still going on underneath that remarkable cliff, by which oxygen is even now abstracted from the atmospheric air that finds its way into the interior of the earth.

On the continent, Longchamp detected this gas in almost all the thermal waters of the Pyrenees; and Dr. Ure found it issuing from the spring of Loueche in Switzerland. I have myself discovered it in many of the thermal waters of France, as in those of Mont Dor and Chaudesaigues in Auvergne, and in those of St. Gervais, Bonneval, and St. Didier in Savoy.

In Spain I detected it almost pure, issuing copiously from the hot spring of Alhama, near Grenada in Andalusia *; and in Italy at Monte Catini, near Pisa in Tuscany, in the hot spring of Torre del Annunziata, mixed with a large excess of carbonic acid, and in the cold spring of Castellamare near Naples.

* The following are the notes I made on the spot. About a mile from the town of Alhama are the hot springs which were known in the time of the Romans, and were in great repute amongst the Moors. They rise out of the bottom of the narrow fissure above-mentioned, just at the point of its southern termination. The rocks are here quite precipitous, and the cleft in them so narrow, that no more room is left than for the rivulet to flow along. The rock is composed entirely of the white compact limestone, which probably belongs to the secondary period, underlying the tertiary, which Col. Silvertop has described. The spring is very copious, discharging twenty-five cubic feet per minute. Its temperature appeared to me to be 106° of Fahr., but this was in the public bath; and at the point at which it issues, it is stated to be 36° R. = 112°·5 Fahr.

Bubbles of gas were given off from it, which I found to consist almost entirely of nitrogen, no more carbonic acid being present than would be absorbed by the water under which the gas was collected. The water was pure and tasteless, containing no iron, but only a trace of lime. It is in repute for the cure of various maladies.

It is not indeed confined wholly to springs possessing an elevated temperature, for I found it in Ireland both in the only thermal spring of that island, namely that at Mallow, and in a cold spring called Holy Well, near Clonmel.

Near Kissingen are several cold springs, accompanied with a copious disengagement of gas, found by Kastner to consist of

Carbonic acid	25·45
Nitrogen	66·50
Oxygen	8·05

A cold spring emitting nitrogen has been observed near Inverkeithing in Scotland *, and Sir R. Murchison has informed me of another of the same kind in Shropshire.

It is needless to remark that this gas is emitted in other quarters of the globe. Dr. John Davy discovered it almost pure, issuing in large quantities from a hot spring near Trincomalee in Ceylon.

In the United States I found it in the hot spring and warm spring already noticed as occurring in the mountain district of Virginia †; at Lebanon in Massachusetts, mixed with about 10 per cent. of oxygen; and at Washita, in the state of Arkansas, with 7·6 per cent. of the same.

Other observers have remarked it issuing from cold springs in Rensselaer county, Vermont; at Chateaugay, in Franklin county, New York; and very copiously near the village of Cayuga, south of the Seneca Falls—the only instance, says the Reporter, of such a phænomenon in the midst of calcareous rocks, all others known in the State of New York being near the junction of transition with those of a primitive or metamorphic character ‡.

The evidence afforded by the universal presence of nitrogen gas in favour of their volcanic origin, will be more fully appreciated when the theory of volcanos is entered upon; suffice it to say at present, that its derivation from volcanic processes cannot be questioned, as, according to Dr. John Davy, the bubbles of gas which escaped from the sea round about the new volcanic island that made its appearance between

* Edin. Phil. Journ. 1829.

† Professor Rogers, in the memoir before referred to, notices it as occurring in various other spots of the same district.

‡ Beck, Geological Survey of the State of New York, 1838.

Sicily and Pantellaria in the year 1830 consisted in part of this gas.

Now it may be observed, that its evolution from the bowels of the earth in a state of purity, or only intermixed with a small amount of oxygen and with carbonic acid, seems to imply some process of combustion, by which oxygen has been abstracted from common air which found its way to the interior of the earth; for had it arisen from the decomposition of organic matter, as some have conjectured, it ought to be accompanied with carburetted hydrogen, as is the case at the floating island of Derwentwater, according to Dr. Dalton. Moreover, no amount of organic matter, that can be supposed to exist in the thermal water, could produce a constant supply of nitrogen equal to 250 cubic feet in twenty-four hours, as at Bath.

Nor, considering its universality and its abundance, can I reconcile myself to the explanation of its origin suggested by Professor Rogers, who, admitting that some process of oxidation is implied, imagines, that the absorption of oxygen by large masses of protoxide of iron, or of carbonaceous matter, which he supposes present in the earth, may account for the emission of nearly pure nitrogen.

Surely such a process can hardly be going on generally enough, and on a sufficiently extensive scale, to give rise to a phænomenon which seems scarcely ever absent where thermal waters exist.

Another gas very commonly found in thermal waters is Sulphuretted Hydrogen, which is contained in almost all of those met with at the foot of the Pyrenees, and, according to Boussingault, in those of the Andes.

Its general connexion with volcanos may be collected from even a cursory glance at the contents of this volume, as there is probably scarcely any volcanic region which does not present it either in its springs or somewhere in its immediate neighbourhood; but it may still be a question whether, when it occurs in connexion with cold springs, it is to be regarded as an indication of latent volcanic action.

There is no doubt indeed, that it can be, and often is, generated by the action of organic matter upon alkaline and earthy

sulphates; but although the occurrence of sulphuretted hydrogen has been explained in this manner at Harrogate, yet Professor John Phillips conceives, that the mineral impregnation of these springs is to be ascribed to the chemical effects specially exerted along the line of a subterranean disturbance which he has there detected, and Sir Roderick Murchison has been led to similar conclusions, with respect to the sulphureous spring of Llanwrtyd in South Wales, by his observations on the geological structure of that locality.

A third kind of air, which in thermal waters may be said to be almost universally present in greater or less abundance, is Carbonic Acid, thus enabling them to hold in solution a larger quantity of calcareous earth than they could otherwise do, a portion of which they deposit on first issuing from the earth, in consequence of the escape of the volatile ingredient by virtue of which it was retained.

Hence those earthy sediments which incrust the surface in many places in which warm springs gush out, and which are denominated variously stalactites, stalagmites, tuffs, &c., according to certain unimportant differences in their appearance and position.

One of the most remarkable of the springs disengaging carbonic acid is that of Kissingen in Bavaria *, which has its regular periods of intermittence and of agitation, evolving under the latter circumstances enormous quantities of gas.

When the spring is in full flow, the great shaft of eight feet in diameter is filled with water, agitated in the most violent manner by the torrents of gas which it discharges.

It resembles a small pan of water boiling on a very hot fire just as rapidly as is possible without overflowing. Whilst this turbulence is at a maximum, the gas abruptly ceases to flow, and in a few seconds the surface of the water in the shaft is perfectly tranquil.

In 1826 the spring, during the latter half of the month of September, ebbed five times daily, the periods of ebb within the same time amounting to 10h. 22m. in twenty-four hours. In October the ebb averaged a fraction more, the times of

* See Professor James Forbes's Memoir in Edin. Phil. Journ. 1839.

ebb only 8h. 39m. The daily product of the spring was 48,034 cubic feet: the volume of gas was not appreciable, but even the first few minutes of returning action of the spring in its feeblest state after ebb, are sufficient to fill the entire shaft (containing 920 cubic feet) with gas.

Gustavus Bischof has enumerated seven groups of thermal waters existing in Germany, alike impregnated with carbonic acid and soda. These are:—

1. The springs of the Eifel and the Siebengebirge.
2. Those of the Westerwald and Taunus.
3. Of the Habichtswald, Meissner, Vogelsgebirge, and Rhöngebirge.
4. Of the Fichtelgebirge.
5. Of the Erzgebirge.
6. Of the Bohemian Mittelgebirge.
7. Of the Riesengebirge in Silesia.

Indeed wherever carbonate of soda is present in a mineral water, we may assume the existence of free carbonic acid, by which its extrication from the felspathic ingredient of the rock has been effected.

Now we have already seen, that a disengagement of carbonic acid takes place copiously from volcanos in all their different phases, and that when it occurs in hollow places or caverns where its diffusion through the atmosphere is checked, it accumulates to such an extent as to render the air unrespirable. Such is the case at the Grotto del Cane near Naples, and the Plutonia noticed by classical writers.

The evolution of carbonic acid is therefore another phænomenon which belongs in common to volcanos and to thermal waters, and hence affords an additional presumption in favour of the idea, that a similar origin is to be assigned to both.

This gas is however given off in various places where thermal waters are not found, impregnating the common springs of the district, and communicating to them that property of dissolving calcareous earth, which causes them to petrify, as it is called, any substance with which they come into contact. Now it will not be difficult to show, that many of these springs likewise derive their gaseous impregnation from vol-

canic agency. Some indeed, as those in various parts of Italy, and in the province of Auvergne in France, are situated in the midst of a volcanic country, and cannot therefore be otherwise considered; whilst many not so placed may nevertheless be conjectured to derive their carbonic acid from this source, on grounds similar to those which have led us to this inference with respect to thermal waters themselves. They often indeed lie in valleys, which from the peculiar position of the strata composing their sides, seem to be produced by the heaving up of the latter all around some central point. These are called *circular valleys* of elevation, and the springs of Pyrmont in Westphalia, long celebrated as chalybeate, rise up through a valley of this description, the sides of which are composed of a succession of beds, all of which dip outwardly from this central point, as will be seen in the woodcut subjoined.

Section of the Circular Valley of Elevation, Pyrmont.

Other cases of carbonated springs in similar positions have been noted, and the existence of valleys of this kind may be readily inferred from what has been already said in the last chapter with respect to the elevation of chains of mountains*.

It seems therefore sufficiently apparent, that thermal, and also in many cases sulphuretted and carbonated springs are connected with those igneous forces which have manifested themselves, not only in spots where volcanos occur, but likewise wherever chains of mountains have been uplifted, or deep fissures in the rocks of the country have been formed.

And the same inference may be drawn from the constancy

* Dr. Buckland has noticed, in the Geological Transactions, vol. ii. new series, several valleys in the newer rocks of this country, formed by the uplifting of strata in the same manner as at Pyrmont. Such is the case with the valley of Newbury, where we find, near Kingsclere, the strata heaved up from the greensand to the chalk, so that the beds of chalk form the edges of the hills on either side of the valley. A similarly formed valley exists at Poxwell near Weymouth.

of temperature and of physical properties, which seems to belong to thermal waters, no less than to other volcanic phænomena, considered with reference to the period of man's observation.

We may gather from occasional notices in ancient writers, that many of the springs now accounted thermal, existed before the Christian æra, under the same conditions of temperature and of gaseous impregnation as at present.

I have already alluded to the evolution of gas from the pool in the valley of Amsanctus, which is a phænomenon of the same character, and may refer to certain of the springs of Greece as confirming the same inference.

Thus Dr. Clarke of Cambridge, in his 'Travels in Greece,' has shown, that the hot springs which gush out from the foot of Mount Œta in Thessaly, at the pass of Thermopylæ, emit at this present time bubbles of gas, which he found to consist of sulphuretted hydrogen.

Now this very spring is mentioned by several ancient writers, and it is remarkable that Sophocles seems to allude to the same phænomenon,—I mean the evolution of gaseous bubbles,—making a poetical use of it in the play of the Trachiniæ. Such at least is the explanation given by Dr. Clarke of the passage in which Deianira describes the poison, given her by the Centaur Nessus, with which she had anointed the tunic prepared for her husband Hercules. Some of the wool which had imbibed this poison being thrown down on the spot where the hot springs now appear, it is said that frothy bubbles rose from the earth.

. . . . εκ δε γης, όθεν
Προυκειτ', αναζεουσι θρομβωδεις αφροι.
Γλαυκης οπωρας ὡστε πιονος ποτου
Χυθεντος εις γην Βακχιας απ' αμπελου*.

In like manner, Dr. Holland in his 'Travels' mentions his having detected, near the coast of Albania, the escape of a stream of inflammable gas, such as is found to take place in

* See also the chorus:
Ω ναυλοχα και πετραια
Θερμα λουτρα, και παγους
Οιτας περιναιεταοντες, &c.

the Apennines between Bologna and Florence, at a spot well-known to most travellers.

And it seems probable, that this same evolution of gas was going on in the times of ancient Greece at the spot in which it was observed by Dr. Holland; for a temple of the Nymphs, which was usually erected in places distinguished by this phænomenon, appears to have existed in this very place, and Dodwell discovered a coin of the city of Apollonia in Albania which bore an evident allusion to this circumstance, as it had represented on one side a figure of Apollo, the patron of the city, and on the other three nymphs dancing round a fire.

Now as in these cases the gas generally rises from the ground in a continued current, it so happens, that when once lighted it may go on burning for ever, and hence a vulgar notion prevails that the gas takes fire spontaneously. When the ancients speak of the spontaneous fire which rose from the peaks of Parnassus, and which contributed to the sacredness of that spot, they no doubt allude to a phænomenon of the same description; and the gas which springs out of the earth at Baku, and in other places near the Caspian, was also the object of peculiar veneration amongst the fire-worshipers of that country.

In the neighbourhood of Grenoble, where the same phænomenon occurs, I once had an opportunity of ascertaining the falsity of the notion that this fire is self-kindled, and the cause of the prevalent opinion that such is the case. When the flame is merely blown out, it lights again immediately, in consequence of the heated condition of the rock through which the current of inflamed gas passes; but when, not contented with extinguishing it, I threw several buckets of water over the stones in its immediate vicinity, the inflammable gas escaped into the air without catching fire, and this object of superstitious dread was easily collected in bottles, and carried off for chemical examination, to the astonishment and alarm of the gaping peasants.

There is also in the Greek Anthology a singular, though inelegant and almost barbarous poem of Paulus Silentiarius (Σιλεντιαριος), chief silence-keeper* to the Emperor Justinian, relating to the hot baths of Pythia in Bithynia, the modern Brusa. In speculating on the cause of the heat, the author [illegible] a theory very similar to that which prevails at present, wit[illegible] to many hot springs not supposed to be connected with vol[illegible]nomena.

* An officer of high dignity in the [illegible]ace of Constantinople.

"It is conceived," he says*, "by some, that there are narrow fissures below the earth; that opposing currents of water meeting from various quarters are compressed, and by that compression acquire no ordinary heat. Others, on the contrary, say, that in the recesses of the earth there are somewhere sulphureous ores; that the neighbouring stream therefore, meeting with a violent heat, from its inability to remain below, rushes upwards in a mass.

"Which opinion will my readers adopt? The former? I do not myself embrace this; I agree with the latter one; for there is a mephitic offensive stench clearly proving it.

"'T was thus the hot bubbling fluid issued for the benefit of mankind,—an inanimate Hippocrates, a Galen untaught by art."

The expression "hot bubbling fluid" evidently implies that bubbles of air were, at the remote period in which the poet wrote, observed escaping from the spring; and that this air consisted of sulphuretted hydrogen appears from a sentence just preceding, where he alludes to the offensive smell which the water gives out.

Now Browne the traveller†, and more lately Hamilton‡, have

---

* Ενερθε γης σηραγγας
ειναι στενας νοουσιν·
ὑδωρ εκειθεν ενθεν
αντιτρεχον πιλεισθαι,
πιλουμενον δε, θερμην
ου την τυχουσαν πασχειν.

Αλλοι λεγουσι τουτο·
μεταλλα που θειωδη
γης εν μυχοις ὑπαρχειν·
το γειτονουν ουν ναμα,
θερμης τυχον βιαιας,
κατω μενειν ουκ ισχον
ανω τρεχειν τῳ πληθει.

Ποιον δεχῃ; το πρωτον;
αλλ' ου δεδεγμαι τουτο·
τῳ δευτερῳ συμφημι.
οδμη γαρ εστιν, οιδας,
μυδωσα, δυσπνοουσα,
τρανον τε μαρτυρουσα.

Οὑτω προηλθε πασι
το θερμοβλυστον ῥειθρον,
'Ιπποκρατης αψυχος,
τεχνης ανευ Γαληνος. (Vol. iv. p. 64.)

† Walpole's Travels in various Countries of the East.

‡ Researches in Asia Minor, vol. i. p. 77.

described this very spring, the one as it existed towards the close of the last century, the other in the year 1836; and it seems to follow from their joint accounts, that its properties have not changed, that the same sulphureous smell is still exhaled, and that sulphuretted hydrogen escapes from it in large quantities*.

With regard indeed to the temperature of mineral springs in general, it may be conjectured that in countries not exposed to present volcanic operations, no sensible alteration has taken place since the earliest notice of them that has come down to us.

If there had been any change, it would probably have been from a higher to a lower degree, rather than the reverse; and as several of the thermal springs which were known and resorted to by the ancients, such as Aix, Mont Dor, Plombières, and Bath, retain at present a heat as great as is tolerable to the human body, it seems evident, that if they had been only in a slight degree hotter in the time of the Romans, they would have required to be cooled down by artificial means before they were employed for bathing, which we are not told was ever the case.

In regarding them however as permanent in their characters, I speak only with reference to the limited range of human observation; for in a geological sense, and viewed in relation to those protracted changes which the globe appears to be undergoing, I see no reason for denying that their excess of temperature may be of transitory duration.

We have already seen, that the degree of their heat has some connexion with the recent date of the volcanic operations with which they are associated, and that some volcanic districts, such as the Hebrides and the north of Ireland, which have been longest extinct, are entirely destitute of them.

Perhaps therefore, if an exact account were taken of their actual temperature, our successors might hereafter detect some slight secular variation, and with a view to this the accurate observations made by Professor James Forbes on

* The temperature of one spring was 184°, of another 190°. The stream of hot water which flows away from the bath, and which has a temperature of 97° Fahr., is inhabited by a particular univalve, the *Melanopsis buccinoidea*, which seems to prefer warm water to cold, as it existed only in the warm stream, and not in a rivulet of cold water close by.—(H. E. S.)

those of the Pyrenees* have set a good example, which others, it is hoped, will imitate.

Be that however as it may, it is not the less certain, that of the three classes of phænomena relative to thermal springs which have successively come before us, each one points to the same conclusion.

Their position, even when it does not bring them into immediate association with active volcanos, is in general such as to favour the suspicion that forces of a similar kind have been in operation in their neighbourhood, and in accordance with this view, their temperature bears often some relation to the probable recent date of the latest symptom of volcanicity.

In the second place, we have seen that the gases emitted from the earth on the spots where these springs make their appearance are the same as those which escape from volcanos, and which are found associated particularly with languid volcanic action; whilst as we compare the phænomena of Vesuvius with those of the Solfatara, or of Volcano, and the latter again with the Crater evolving merely steam which occurs in New Zealand, we trace so many successive links binding together the processes of volcanos and of thermal springs. Thirdly, it has been shown, that this class of waters, as well as others not thermal, which contain some definite gaseous impregnation, do not seem of transitory duration, but to possess the same permanency of character, or what appears to our limited views as such, which volcanos themselves exhibit.

If it be said, that the high temperature of a spring only proves the great depth from whence it is derived, inasmuch as even in the basin of Paris water of the temperature of 82° has been obtained by sinking as low as 548 mètres, I would reply, that the very fact stated affords to my mind the strongest presumption in favour of these views, since it shows that the gases which indicate the connexion between thermal waters and volcanos do not make their appearance, where springs arise from a great depth, in spots where volcanic action is not going on.

The rarity indeed of thermal waters unattended with gaseous impregnations of the kind alluded to, or where the

* Philosophical Transactions for 1836.

body is sparingly soluble, with bubbles of the gas accompanying the spring, seems to indicate, that volcanic action at one period or another must have been instrumental, in creating and in keeping open the fissures or channels of communication, through which water could reach the surface from the necessary depth.

Moreover, in the few cases in which either simple thermal waters, or sulphureous ones of any temperature, may be inferred to have no connexion with volcanos, or at least with existing volcanic action, the former have not the gaseous impregnation, nor the latter the permanency of character, which belong to the springs we have been considering.

In Ischia, for example, I have given in my 13th chapter a list of springs, possessing a high temperature, but free from gases of all descriptions, which obviously derive that excess from the heat which pervades the rocks of the island. Fodère* has mentioned some of the same nature in the Maritime Alps, and Anglada† in the Pyrenees, which go by the name of *simple thermal waters*. The former would seem to derive their heat from the decomposition of pyrites, to which may be owing the formation of the beds of gypsum from which they spring; the latter are regarded by Anglada, as having borrowed it from the rock warmed by the passage of heated gases through its substance.

And when a sulphureous spring arises from the decomposition of pyrites or of alkaline sulphates, I suspect it will be frequently found to vary materially in point of strength within short intervals of time. Thus one at Willoughby in Warwickshire yielded me, in the autumn of 1828, 16·9 cubic inches of sulphuretted hydrogen to the gallon; in the April following I could detect only 12·65 cubic inches; and in the autumn of 1834 only 5·2.

No such rapid changes in the amount of the gases disengaged have been noticed in the case either of thermal springs, or of those connected with them, except perhaps after the occurrence of earthquakes or other great physical convulsions.

But perhaps the most conclusive argument in favour of the

* Voyages aux Alpes Maritimes, p. 155.

† Anglada, Traité des Eaux Minérales, vol. ii. p. 170.

connexion of thermal waters with volcanos is of a negative kind—I mean their entire absence over vast tracts of country where no volcanic appearances exist.

It appears indeed, from the statements of Scherer, in his work on the mineral waters of the Russian empire, now confirmed by the extended researches of Sir Roderick Murchison and his companions, that neither thermal nor acidulated springs occur in any part of that vast tract, till we approach the mountains of the Caucasus and the Ural, or the volcanos of Kamtschatka.

Upon the whole then, I think it may be fairly concluded, that thermal waters in general afford indications of the more languid and continuous operation of that internal Force, which manifests itself in the volcano and in the earthquake, and that its consideration consequently deserves a place in a treatise dedicated to such a subject.

I will therefore terminate this chapter by a tabular view of the principal thermal springs which have been examined with any pretensions to accuracy, exhibiting their physical as well as their chemical characters—their temperature, no less than their principal gaseous and mineral accompaniments.

But in order to convey some sort of idea of the relative intensity of the force to which their superior heat is attributable, I shall set down only the excess of their temperature above that which I have supposed to represent the mean of the climate at the spot where they appear, and not that which they have been actually ascertained to possess. This method however can give rise to no mistake, as the reader, in order to learn the true temperature of a spring, has only to add together the number in the sixth column, representing the excess of temperature, and that given in the first as the mean temperature of the spot; the latter is indeed liable to much uncertainty, and can only present an approximation to the truth, as no allowance is made for the elevation of the locality: but it may serve the purpose intended, by preventing the confusion which might arise in the mind, from seeing, for instance, a spring in the tropics stand higher in the scale, because it elevates the thermometer to a higher point, than one in a colder climate, which exceeded by a greater number of degrees the mean of the country in which it occurs.

Catalogu

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cu evolved in 24 h Water.	
British Islands. N. Lat. 55° to 51°. W. Long. 1° to 5°. Mean temp. reckoned about 49°*.	Bath	New red sandstone	Somersetshire	0	King's Bath 66°	King's Bath 28,339	Ki 2
	Bristol	Carboniferous limestone in a valley of disruption	Gloucestersh.	0	Hot Well 25	...	...
	Buxton	Ditto	Derbyshire	4	St. Anne's 33	St. Anne's 13,500	St.
	Bakewell	Ditto	Ditto	3	Bath Spring 13	...	...
	Stony Middleton	Ditto	Ditto	4	—— 14	...	...
	Taafe's Well	Coal strata	Near Cardiff, S. Wales	0	—— 21	...	
	Mallow	Carboniferous limestone	County of Cork, Ireland	0	Spa Well 23	...	...
Germany. N. Lat. 51° to 49°. W. Long. 24° to 32°. Mean temp. reckoned about 50°.	Bertrich	Connected with extinct volcanos	Near Treves, Eifel	4	40	7240	...
	Aix la Chapelle	At the junction of clay-slate and carboniferous limestone	Lower Rhine Province	4	Kaiserquelle 85·5	...	...
	Borset	Ditto	Ditto	4	Mühlenbend 121·5	...	...
	Ems	Clay-slate	Nassau	3	Rondeel 81	12,400	...
	Wiesbaden	Chlorite slate	Ditto	3	Kochbrunnen 108	84,092	...
	Schlangenbad	Clay-slate	Ditto	4	Schachtbrunnen 27	21,328	...
	Soden	Ditto	Near Frankfort on the Maine	3	Gemeindebrunnen 20	...	...
	Kreutznach	Felspar porphyry	Lower Rhine Province	3	Münster am Stein 36	...	...
	Kissingen	Muschelkalk	Bavaria	6	Soolensprudel 17	48,034	...

* N.B. In this estimate of mean temperature, as no allowance is made for height, it is evident Buxton, Bakewell, &c.

† Where the name of the spring is not given, the number is understood to indicate the amount ev

‡ N.B. Where not otherwise specified, the spring alluded to in this and the next column is assum

§ The ingredients present only in minute quantities are printed in italics.

Thermal Springs.

ases evolved & their relative roportions one to the other.				Gaseous contents.	Solid contents.		
acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated ‡.	Nature of the more abundant and of the more active ingredients present.	According to
				C.In.	Grs.		
to 13	3·5	96·5	Daubeny ...	Carbonic acid 1·2	King's Bath 15	Mur. lime and magnesia; *iron* (*Iodine, Cuff.*)§.	Phillips.
0	8	92	Ditto	Carbonic acid 3·750 Common air 0·375	Hot Well 5·95	Sulph. soda, mur. of lime .	Carrick.
0	0	100	Pearson ...	Carbonic acid 0·187 Azote 0·580	St. Anne's 1·875	Mur. magn. and of soda ...	Scudamor
0	0	100	Daubeny ...	....	Bath Spring 3·5	Sulph. of lime, mur. of soda	Daubeny.
0	0	100	Ditto	....	Warm Spring 2·0	Sulph. of soda and mag., mur. lime	Ditto.
0	3·5	96·5	Ditto	....	——— 1·2	Sulphate of magnesia	Ditto.
0	6·5	93·5	Ditto	....	Spa Well 0·3	Carbonate of lime	Ditto.
....	.....	......	....	Carb. acid, with a trace of sulph. hyd.	18·267	Carb. and sulph. of soda; *Lithia, potass*	Funke.
30	.....	69·5	Monheim...	Sulphuretted hydrogen	Kaiserquelle 31·95	Mur., carb., and sulph., soda; *Sulphuret of sodium, phosph. soda*	Monheim
18	2	80	Daubeny ...	Carbonic acid 7·6 Nitrogen 19·0	Mühlenbend 34·0	Mur., carb., and sulph., of soda; *Lithia, strontian, fluoric acid*	Ditto.
00	0	0	Ditto	Carbonic acid	Kesselbrunnen 28·9	Carb., mur., and sulph., soda; *Strontian, barytes, phosph.* and *fluoric acids*	Kastner a Struve.
73	0	27	Ditto	Ditto	Kochbrunnen 57·59	Mur. of soda, lime, and potass; *Bromine, manganese,* and *fluoric acid*	Ditto.
....	.....	......	....	Carbonic acid with a little nitrogen	Schachtbrunn 6·0	Carb. of soda, muriate of soda	Fenner.
....	.....	......	....	Carbonic acid	Saltzquelle unter der Brucke 119·8	Mur. of soda; *Potass, bromine*	Schweinberg.
....	.....	......	....	....	Theodorshall 87·9	Mur. of soda, lime, and magnesia; *Potass, alumina phosphoric, acid*	Prieger.
00 arly.	0	Trace	Forbes	Carbonic acid	Soolensprudel 169	Mur. of soda 107 gr., and other ingredients of sea-water, nearly in the same proportions as in it.	Kastner.

a deduction must be made in all cases where the spring is placed above the level of the sea, as

from all the thermal springs belonging to the locality.
be the same as that of which the composition is given.

Catalogue of Thern

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cub evolved in 24 h Water.	C
N. Lat. 51° to 49°. W. Long. 24° to 32°. Mean temperature estimated at about 50°.	Wolkenstein ...	Mica slate	Saxony........	13	33°·5	....	....
	Wiesenbad	Ditto	Ditto	13	20·0	....	....
	Carlsbad	Granite, in a valley of disruption	Bohemia	11	Sprudel 117·0	Sprudel 111,715	....
	Bilin..............	Gneiss	Ditto	6	16·0	12,288	....
	Töplitz............	Volcanic porphyry	Ditto	6	Hauptquelle 71·0	77,250	....
	Warmbrunn......	At the foot of a granitic chain	Silesia	10	Trinkquelle 47	....	....
	Landeck	Gneiss	Ditto	14	Old Bath 35·5	12,960	....
Germany*. N. Lat. 48° to 46°. W. Long. 26° to 30°. Mean temp. estimated at about 51°.	Wildbad	Granite	Wirtemburg...	13	Hauptquelle 47	....	....
	Baden-baden ...	Ditto	Duchy of Baden	4	Ditto 96·4 F.†	12,033	....
	Baden-weiler ...	Ditto	Ditto	......	30·5	....	....
	Baden	Jura limestone	Austria.........	6	68·5	Haupt-quelle 40,950	....
	Gastein...........	Granite	Saltzburg Alps	30	66·5	4 principal springs 100,080	....

* This, however, is far above the mark with reference to the majority of springs enumerated, in co

† Within the same range of latitude as the above occur the following thermal springs, few of wh as stated below, viz.

In Moravia.

Uttersdorff .... 37°·25
Töplitz .... 12·00

In Styria.

Doppelbad, near Gratz 32°·75 F.
Römerbad, near Cilli ... 48·00
Neuhaus, near Cilli ...... 46·25

In Carinthia.

Töplitza 4
Montfalcone, near Trieste. 5

In the Tyrol.

On the Brenner 2

Springs. (Continued.)

Gases evolved and their relative proportions one to the other.				Gaseous contents.	Solid contents.		
Carbonic acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
				C. In.	Grs.		
4	2	98	Daubeny ...	Carbonic acid	1·845	Carbonate of soda	Kuhn.
8	2	98	Ditto	Ditto	4·03	Carb., sulph., and mur. of soda	Lampadiu
......	......	......	....	Ditto 11·85	49·6	Sulph. and carb. of soda; *Strontian, manganese, fluoric* and *phosph. acids*	Berzelius.
......	......	......	....	Ditto 33·58	39·2	Carb., sulph., and muriate of soda; *Lithia, potass,* and *manganese, phosph. acid*	Steinman
......	......	......	....	Ditto 2·4	15·6	Carb. and sulph. of soda; *Phosph. acid* (Berzelius)	Ambrozzi
0	5·3	94·7	Daubeny ...	Nitrogen 0·735 Sulph. hyd. 6.6 to 8.0	4·77	Sulph. and carb. of soda; *Carb. of ammonia*	Tschortne
2	0	100	Ditto	Carbonic acid 1·00 Sulph. hyd. 4·33	2·62	Sulph. and mur. of soda.	
2·00	6·44	91·56	Weiss	Carbonic acid 12·00 Nitrogen 79·25 Oxygen 8·25	3·59	Mur., carb., and sulph. of soda	Sigwort a Weiss.
......	......	......	....	Carbonic acid	26·331	Mur. of soda and of lime, sulph. of lime, silica	Otto and Wolf.
......	......	......	....	Ditto	1·7	Chiefly carb. of lime	Schmidt.
......	......	......	....	Sulph. hyd. 3·33 Carbonic acid 1·77	1·076	Sulph., lime and magnesia	Schenk.
......	......	......	....	Carbonic acid	2·7182	Sulph. of soda, mur. of soda, and potass	Hünefeld.

quence of their high elevation.

have been sufficiently examined, but which exceed the assumed mean temperature (51°) of the clim

In Croatia.		*In Hungary.*		*In Hungary.*	
Töplika	82°·25	Ofen, or Buda	93°·5	Szalathny........................	9
Krapina	62·	Trencsin	53·0	Lucaka............................	26
Szulinczha	53·	Pöstheny, near Presburg...	95·75	Glasshütte, near Schemnitz	53
Lipiker	73·25	Ribar, near Neusohl	27·80	Eisenbach, near ditto.........	53
Stubicza	21·25	Altsohl, near ditto	32·75	Parad, near Erlau	35
		Stuben, near Kremnitz ...	59·75	Szobranez, near Unghoar ...	19
		Gran..........................	13·9	Budos, near Fünfkirchen ...	86

Catalogue of Therm

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic … evolved in 24 hou… Water.	Ga…
France. From Lat. 51° to 47°. Long. 1° to 5°. Assumed mean temp. 51° Fahr.	St. Amand	Slate covering the coal formation	Near Valenciennes, Dép. du Nord	……	28°	…………	……
	Bourbonne les Bains	Granite, covered by Jura limestone	Connected with the chain of the Vosges. Nr. Chaumont, Dép. Haute Marne	……	La Fontaine 80	2 springs 2,916	……
	Luxeuil	Granite, covered with sandstone	Near Veseul, Dép. de Haute Saone	……	Grand Bain 75·5	8,640	……
	Plombières	Granite	Near Epinal, Dép. de Vosges	13	Ditto 95·75	9,000	……
	Bains	Ditto	Near ditto, ditto	……	Grosse Source 71	…………	……
	Bagnoles	Ditto	Near Alençon, Dép. d'Orne	……	28	…………	……
France. From Lat. 47° to 44°. Long. 0° to 4°. Assumed mean temp. 56° Fahr.	Bourbonne l'Archambault	Slate formation	Connected with the volcanic chain of Central France. Near Moulins, Dép. de l'Allier	……	Grand Puits 69	Grand Puits 86,400	……
	Bourbon Lancy	Ditto	Near ditto, ditto	……	Ecures 84	10,800	……
	Vichy	Coal formation, covering granite	Near Gannat, Dép. de l'Allier	……	Bassin des Bains 57	9,360	……
	Neris	Sandstone and coal, resting on granite	Nr. Montluçon, Dép. de l'Allier	……	Puits de Cesar 89·5	19,800	……
	Mont Dor	Trachyte	Near Clermont, Dép. de Puy de Dôme	34	Bains de Cesar 52 F.	12,780	Bains Cesa… 4,
	Bourboule	Ditto	Ditto	28	65 F.	…………	……
	St. Nectaire	Ditto	Ditto	……	Gros Bouillon 45·75	…………	……
	Chaudesaigues	Gneiss	Nr. Aurillac, Dép. de Cantal	……	Par 118·0	307,188	No. 1 2 3

* The mark (*) indicates that the g

Springs. (Continued.)

Gases evolved and their relative proportions one to the other.				Gaseous contents.	Solid contents.		
Carbonic acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
					Grs.		
......	......	......	....	Sulphuretted hyd. ...	....	Sulphuret of sodium, sulphate of soda, and magnesia.	
0 18	0 4·5	100 77·49	Longchamp Athenas	....	52	Muriates of soda and lime, sulphates of lime and magnesia	Athenas.
......	......	......	....	....	....	Muriates and sulphates of soda, lime, and magnesia.	
......	......	......	....	....	....	Muriates and sulphates of soda, magnesia, and lime	Vauquelin.
......	......	......	....	....	....	Muriates of soda, lime, and magnesia.	
*	......	*	Longchamp	....	....	Muriates of soda, magnesia, and lime.	
*	......	*	Longchamp	Carbonic acid	....	Mur. soda, sulph. soda.	
......	......	......	....	Ditto	13·478	Mur. of soda and potass, sulph. soda and lime	Puvis.
100	0	0	Longchamp	Ditto	Source des Celestins 62	Carb., mur., and sulph. of soda	Longchamp
......	......	100	Ditto	....	....	Carb., mur., and sulph. of soda.	
00·0	0·85	9·15	Daubeny ...	Carbonic acid	Source de la Madelaine 11·4	Carb., mur., and sulph. of soda	Bertrand.
......	......	......	....	Ditto	Source des Fièvres 18·2	Muriate of soda.	
......	......	......	....	Ditto	2nd Spring 50·0	Carb., sulph., and mur. of soda	Bouillay and Henry.
57 60 37	13 15 1	30 25 12	Daubeny ...	....	Source de Par 14·5	Carb. and mur. of soda, magnesia, lime, and oxide of iron	Chevallier.

exists, but that its proportion is unknown.

Catalogue of Thermal

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours of Water.	Gas.
From Lat. 47° to 44°. Long. 0° to 4°. Mean temp. 56° Fahr.	Château-neuf ...	Volcanic rocks............	Con. with volcanic chain of Central France. Near Gannat, Dép. de Puy de Dôme	......	Grand Bains 45·75°	....	....
	Evaux	Granite	Near Neris, Dép. de Creuse	......	Puits de Cesar 81·75	....	....
	Saint Laurent ...	Tertiary limestone, covering granite, with volcanic rocks near	Near Aubenas, Dép. d'Ardeche	......	66	....	....
	Bagnoles	Ditto	Nr. Mende, Dép. de Lozère	......	57	6,192	....
	Digne	Limestone in inclined strata	Con. with the Alps of Dauphiny. Dép. des Basses Alpes	......	Bassin de l'Etuve 59·25	....	....
France. From Lat. 44° to 42°. W. Long. 4° to E. Long. 4°. Assumed mean temp. 60° Fahr.	Greoulx	Limestone in inclined strata	Dép. des Hautes Alpes	......	41·75	....	....
	Aix	Jura limestone, dislocated and inclined	Dép. des Bouches du Rhone	......	Sextius 39·0	....	....
	Balaruc	Jura limestone, near the volcano of Agde	Nr. Cette, Dép. d'Herault	......	Varying from 66 to 52	....	....
	Sylvanes	Granite	Connected with the chain of the Pyrenees. Near St. Affrique, Dép. de l'Aveyron	......	48	....	....
	Rennes............	Sandstone, breccia, and limestone, belonging to the coal formation, highly inclined	Near Limoux, Départ. d'Aude	......	Bainfut 53·0	....	....
	Campagne	Ditto	Ditto	......	21·5	....	....
	St. Paul de Fenouilhades	From a fault in limestone, covering slate	Near Caudies, Dép. d'Aude	......	21·5		
	Arles	Granite near its junction with limestone	Dép. de Pyrenées Orientales. Valley of the Haut Segre.	9	Petit Escaldadou 85·3 F.	36,357	....
	Preste	Granite		......	Source d'Apollon 71·0	10,888	....
	Vernet	Junction of granite with stratified rocks	Valley of the Tet.	17	Source intérieur 72·2	2,455,668	....
	Molitg	Granite		......	Grande Source 40	3 springs 1,170	....
	Thuez	Granite and serpentine .		27	Source du Torrent Réal 111·5	....	....
	St. Thomas	Mica-slate, resting on a quartzose granite		......	No. 1 75		
	Canavilles			......	69·5		

Springs. (Continued.)

Gases evolved and their relative proportions one to the other.				Gaseous contents.	Solid contents.		
Carbonic acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
				C.In.	Grs.		
......	......	......	....	Carbonic acid.			
......	......	......	....	Ditto	....	Carb., sulph., and mur. of soda.	
......	.. ...	......	....	....	....	Carb., mur., and sulph. of soda.	
......	......	......	....	....	....	Mur. of magnesia and sulph. of lime.	
......	......	......	....	Sulphur. hydr.........	14·3	Sulphate of magnesia and lime, mur. of soda.	
......	......	......	....	Carbonic acid, sulph. hydrogen	25·32	Mur. of soda and magnesia.	
......	......	......	....	....	1·5	Carb. of magnesia and lime, sulph. of lime	Robert.
......	......	......	....	Carbonic acid 6·0	....	Mur. of soda and magnesia, and lime, carb. of lime	Figuer.
......	......	......	....	....	....	Mur. and sulph. of soda and magnesia.	
wholly	......	......	....	Carbonic acid	12·0	Oxide of iron.	
......	......	wholly	Anglada ...	Nitrogen and oxygen	2·0	Sulphuret of sodium, soda, caustic and combined with sulphuric acid	Anglada.
......	......		Ditto	....	0·978	Ditto	Ditto.
......	......		Ditto	....	1·311	Ditto	Ditto.
......	......		Ditto	....	1·326	Ditto	Ditto.
......	......	......	....	....	0·984	Ditto	Ditto.

Catalogue of Thermal

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic fee evolved in 24 hours o	
						Water.	Gas.
France. N. Latitude 44° to 42°. W. Longitude 4° to E. Longitude 4°. Assumed mean temperature 60° Fahr.	Sorede	From granitic pebbles...	Connected with the chain of the Pyrenees. Dép. des Pyrénées Orientales. Arrond. de Ceret.	......	Font Agre 9°	....	....
	Reynez	Mica slate		......	Beu Calde 23·75	....	....
	Enn	Mica slate, resting on a saccharoid limestone	Arrond. de Prades.	......	62	....	....
	Thuez	Junction of granite with limestone along a line of fissure		......	Source d'Exhalade 71	....	....
	Escaldas	Granite near its contact with slate	Valley of the Tech.	47	Buvette 47·1 F.	28,609	53
	Dorres	Like Escaldas		48	44·4 F.	....	....
	Los	....		......	Source Gervais 24·25	....	....
	Ax	At the boundary-line of granite and slate	Dép. d'Ariege, near Tarascon	25	Source des Canons 108·0	....	....
	Ussat	Limestone, with granite contiguous	Ditto, do.	......	40·0	18,000	....
	Lez	Granite	Valley of	......	Source A 26·4 F.		
	Bagnères de Luchon	Granite near its junction with clay-slate	Dép. de HauteGaronne	20	Grotte supérieur 79·1 F. 77·75	....	....
	Encausse	Limestone	Dép. de HauteGaronne, nr. St. Gaudens	......	6·0	....	....
	Bagnères de Bigorre	Limestone resting on clay-slate, with patches of granite near it	Dép. des Hautes Pyrénées	20	Dauphin 59·0 F.	....	....
	Capvern	Limestone	Dép. des Hautes Pyrénées, near Bagnères de Bigorre	......	15·	....	....
	Barèges	Clay-slates, with hornblende; granite not far distant	Dép. des Hautes Pyrénées	42	Grande Douche 51·9 F.	....	....
	St. Sauveur	Slaty limestone, with hornblende slates adjacent; granite not far distant	Ditto......	25	La Houtalade 8·5 F.	....	....
	Cauterets.........	Clay-slate, with hornblende in nearly vertical beds, near the contact with granite	Ditto......	31	Source des Œufs 70·1 F.	Source de Pauze alone 1,326 All the springs 12,240	Source d Pauze 61·

Springs. (Continued.)

Gases evolved and their relative proportions one to the other.				Gaseous contents.	Solid contents.		
Carbonic acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	Accord[ing] to
100	......	......	Anglada.	Carbonic acid	Grs. 6·8	Carb., sulph., and mur. of soda; *oxide of iron*	Anglad[a]
0	0	0	Ditto	....	....	Sulph. of lime and soda, mur. of soda	Ditto.
0	0	0	Ditto	....	*Very small*.........	Ditto	Ditto.
0	0	0	Ditto	....	....	Ditto	Ditto.
0	0	100	Ditto	....	1·02	Hydrosulphuret of soda, with soda and potass, caustic? sulph. of soda?	Ditto.
0	0	100	Ditto	....	....	Ditto	Ditto.
0	0	100	Ditto	....	....	Ditto	Ditto.
......	......	......	....	....	....	Hydrosulphuret of sodium, caustic soda.	
......	......	......	....	....	....	Sulph. and mur. of mag.	
......	......	......	....	....	2·2	Sulphuret of sodium, carb., sulphate, mur. of soda.	
......	......	......	....	Carbonic acid	....	Sulph. of lime, magnesia and soda.	
......	......	......	....	Ditto	Source de la Reine 1·37	Sulph. of lime, magnesia, and soda, mur. of magnesia and soda	Gauder[ax]
......	......	......	....	Ditto	8·0	Sulph. of lime and mag.	Save.
0	0	100	Longchamp	....	2·3	Sulphuret of sodium, caustic soda, sulph. of soda.	
......	......	......	....	....	1·1	Ditto.	
0	0	100	Longchamp	....	Le Pré 29		

Catalogue of Thermal

Region		Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours of Water.	Gas.
Assumed mean temp. 60° Fahr.	Connected with the chain of the Pyrenees.	Eaux Bonnes …	In a valley of disruption, from highly inclined beds of limestone, near its contact with granite	Dép. des Basses Pyrénées	26	Source Vieille 32·0° 31·4 F.	……	……
		Eaux Chaudes…	In a valley of disruption, at the junction of granite with inclined beds of limestone	Ditto ……	22	Clot 34·6 F.	3,924	……
		Cambo …………	Clay-slate in inclined strata, resting on granite	Ditto ……	……	10	……	……
		Dax ……………	Compact limestone, with trap near it	Dép. des Landes	……	82·25		
		Barboutan ……	Tertiary? ………	Dép. de Gers	……	44	……	……
		Castera-vivant…	Tertiary? ………	Ditto ……	……	25	……	……
N. Lat. 48° to 46°. E. Long. 6° to 16. Assumed mean temp. 49°.		Pfeffers ………	Disrupted beds of limestone	Canton of St. Gall	23	From 50·5 to 51·0 48·9 F.	Very variable, greatest in summer (=429,120), least in winter.	……
		Vals ……………	Clay-slate and compact limestone	Valley of Lugnitz, canton of Grisons	……	14	……	……
		Weissenburg …	………	Canton of Berne	27	32·5 F.	1,423	……
		Loueche ………	Disrupted beds of limestone, with granite not far distant	Canton of Valais	47	74·1 F.	161,364	……
		Baden …………	………	Canton of Argau	10	St. Verene 78·0	One spring 186,325	……
		Schinznach ……	………	Ditto ………	10	39·25 varying a degree or so	……	……
		Yverdun ………	………	Canton of Neuchâtel	13	27	……	……

Springs. (Continued.)

Gases evolved and their relative proportions one to the other.				Gaseous contents.	Solid contents.		
Carbonic acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	Acco[rding] t[o]
				C.In.	Grs.		
......	......	......	....	....	0·949	Sulphuret of sodium, caustic soda, sulph. of lime.	
......	......	......	....	....	6·000	Sulph. of magnesia, mur. of soda and magnesia	Poumi
......	......	......	....	....	1·5	Sulph. and mur. of mag.	
......	......	......	....	Sulphuretted hyd.			
......	......	......	....	Ditto	....	Sulph. of soda and mur. of lime.	
......	......	......	....	....	2·61	Sulphate of soda and magnesia, muriate of soda and magnesia	Capell
......	......	......	....	....	17·3	Sulph. of lime and soda, carbonate of lime	Ditto.
......	......	......	....	Carbonic acid	21·1	Sulphates of lime, soda, and magnesia	Brunn
0	0	100	Ure	Ditto	21·47	Sulphate of lime, magnesia, and soda	Morel
......	......	......	....	Ditto 2·56 Sulphuretted hyd.	32·29	Sulph. of lime, muriate of soda and mag., sulph. of soda	Bauho
......	......	......	....	Ditto 6·0 Carbonic acid 2·3	27·0	Sulphate of lime and soda, mur. of soda and mag., oxide of iron	Ditto.
......	......	......	....	....	0·983	Muriate of soda, sulph. of lime, carb. of soda	Morel

Catalogue of Thermal

	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours of	
						Water.	Gas.
Assumed mean temp. 50°.	St. Gervais	Talc slate..................	Near Sallenche	17	56·50°	1,440	....
	St. Martino	Gritty dark-coloured sandstone	Near Worms, in the canton of Valteline	50	Varies from 68 to 46	....	....
	Aix	....	Near Chambery	......	67·0	....	....
	Bonneval	....	Tarantaise, nr. Burg St. Maurice	......	....	....	....
	La Perrier	....	Near Moutiers, Tarantaise	14	49·5	....	....
	Moutiers	....	Tarantaise ...	......	47·25	....	....
	Echaillon	....	Maurienne ...	......	39·6		
	Courmayeur......	....	Valley of Aoste	......	14·5	....	....
	St. Didier.........	....	Valley of Aoste	......	20·25	....	....

Italy*.

N. Lat. 45° to 43°. Mean temp. 60°.

edmont ...	Acqui, excess of temperature	
	Acqua della Bollente.........	107°· F.
	Valdieri	86·75
	Vinadio	93·50
	Craveggia	21·50
	Bobbio	
	Acqua Santa, near Genoa...	17·
	La Penna, near Voltri	17·
	Roccabigliera, near Nice ...	21·5
mbardy ...	Abano, near Padua	121·0
iscany	Lucca	64·
	Monte Cerboli	50·
	Pisa	46·
	Monte Catini	22·†
palStates	Nocera	

Italy.

N. Lat. 43° to 40°. Mean temp. assumed to be 61°.

Bagni de San Filippo........................	49°· F.
Bagni de Vignone (the Reservoir).........	
Viterbo, Bullicami (the Lake)	19·
Civita Vecchia	25·
Civillina	
Puzzuoli, Temple of Serapis	37·5
Baths of Nero................................	121·2
Pisciarelli	51·0
Torre del Annunziata.......................	26·

* It is worth remarking, that all the thermal waters in Central and Southern Italy lie on the western tions of volcanic action.

† At the Reservoir evolves gas consisting of 10 carbonic acid, 2 oxygen, 98 nitrogen. (*Daubeny.*)

Springs. (Continued.)

Gases evolved and their relative proportions one to the other.				Gaseous contents.	Solid contents.		
Carbonic acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	Acco t
......	......	chiefly	Daubeny ...	Carbonic acid	Grs. 45·47	Sulphate of soda and lime, mur. of soda and mag.	Pictet
......	......	......	....	....	33·3	Sulphate of soda and lime, carb. of lime and mag.	Dema
0	0	100	Gimbernat..	Carbonic acid, sulph. hydrogen	Sulphur spring 4·0	Sulphate of lime, soda, and mag., muriate mag. and soda	Thiba
12	0	88	Daubeny.				
10	0	90	Socquet ...	Carbonic acid, sulph. hydrogen, trace	58·1	Sulphate of lime, soda, and mag., mur. of mag.	Socqu
......	......	......	....	....	....	A strong brine spring.	
......	......	......	Daubeny ...	Carbonic acid	....	Mur. soda and mag., sulph. of lime and alumina, oxide of iron	Ruffin
......	......	......	Ditto	Ditto	....	Mur. soda, sulph. of mag. and lime, oxide of iron	Ditto.

Islands connected geographically with Italy, and in the same latitude, viz.:

N. Lat. 43° to 40°. Mean temp. 61°.

Gurgitello, *Ischia*, varies from 83°·5 to 94°·5 ...	88° F.
Aqua de Cappone, *Ischia*..................	27·25
Olmitello	44·00
Citara	62·00
Bagni d'Ischia	52·00
La Restituta	62·00
Coquinas, *Sardinia*	98·
Acqua Cotta	44·
Benetutti	39·
Sardara	50·
Guitera, *Corsica*	61·
Guagno	57·

Italy and adjacent islands.

N. Lat. 40° to 37°. E. Long. 13° to 19°

Assumed mean temp. 63°.

Santa Eufemia, *in Calabria* ....

Bagni di Lipari, *Island of Lipari* ....

Termini, *Sicily*...................................

Trepani, sulphureous, hot ....

Sciacca, Baths of Saint Calogero ....

flank of the Apennines; that bordering on the Adriatic being destitute alike of these and of other

Spanish Peninsula.

N. Lat. 41° to 36°. W. Long. 9° to E. Long. 1°.
Mean temp. not sufficiently ascertained.

Along the line of the Pyrenees.

Catalonia.—Malavilla, near Gerona; Estruc, Momboy, near Barcelona.

Aragon.—Pantecosa, and Tiermas, 91°·5 F., near Jaen; Albama, near Catalayud.

Mountains of the North-Western Provinces.

Galicia.—Caldas de Reyos, 102° F., Cuntis, 102° F., and Carbello, 75° F., near Santiago.

Leon.—Almeida; Ledisma, 104° F., near Salamanca.

Old Castille.—Arnidello, 107° F., near Calahorra.

Sierra Morena range.

Estremadura.—Banos, near Matagotir.

New Castille.—Trillo, 91°·5 F., near Cifuentes; Sacedon, 71°·5 F., near Hueta; Fuencaliente in La Mancha.

Sierra Nevada range.

Grenada.—Baza, 86° F.; Almeria, 107° F.; Graena, 89° F.; Alhama, 112°·5 F.

Volcanic rocks of the South-Eastern Provinces.

Murcia.—Archena, 113° F., near Murcia; Buzot, 104° F., near Alicant.

Valencia.—Villavieja, 75° F., near Valencia.

In Portugal.

Province of Minho.—1. San Antonio das Taipas, or Caldas das Taipas, near Guimarens, sulphureous, 91° F.; 2. Caldellas de Rendusa, 89°; 3. Canaveres, near Guimarens, sulphureous, 93°·2; 4. Guimarens, sulphureous, 138°; 5. Monçao, near Ucana, 109°·4.

Province of Tra los Montes.—1. Carlao, Villa-real, sulphureous, 92°·8; 2. Chaves, near Braganza, alkaline, 141°·8; 3. Pombal d'Anicaes, near Torre de Moncorvo, sulphureous, 95°; 4. Ponte de Cavez, Villa-real, sulphureous, 74°·75; 5. Rede de Corvaceira, de Moledo, de Panaguiao, 98°·6.

Province of Beira.—1. Alcafache, near Viseu, 98·6; 2. Aregos, near Lamego, 142°·25; 3. Canas de Senhorim, near Viseu, 93°·2; 4. Carvalhal, near Viseu, 98°·6; 5. Santa Gemil, or Lagiosa, near Viseu, 120°·2; 6. San Pedro Dosul, near Viseu, 153°·5; 7. Penagarcia, or Caldas di Monsortinho, near Castelbranco, 68°; 8. Penamaçon, 68°; 9. Prunto, Azenha, or Vinha da Rainha, near Coimbra, 89°·6; 10. Ranhados, near Pinhel, 107°·6; 11. Rapoila de Coa, near Castelbranco, 93°·2; 12. Unhaes da Serra, near Guarda, 87°·8.

N.B. All the above are sulphureous, excepting Penamaçon.

Province of Estremadura.—1. Caldas da Rainhas, near Alemquer, sulphureous, 93°·2; 2. Cascaes, or Estoril, Torres Vedras, 84°·2; 3. Gaieiras, near Alemquer, sulphureous, 91°·4; 4. Leyria, 77°; 5. Lisbon, sulphureous, 86°; 6. Miorga, Alcobaça, 82°·4; 7. Povea de Coz, Alcobaco, 77°; 8. Rio-Real, Alemquer, sulphureous, 75°·2; 9. Torres Vedras, 111°·2; 10. Agua santa de Vimeiro, 78°·8.

Province of Alentijo.—1. Cabeço de Vide, 80°·6.

Province of Algarves.—1. Monchique, near Lagos, sulphureous, 92°·7; 2. Tavira, 75°·50.

Provinces of European Turkey.

N. Lat. 46° to 41°. E. Long. 17° to 29°.

Mean temp. not sufficiently ascertained.

Line of thermal waters extends from north to south in Servia, at the foot of the chain of mountains which connects the Carpathians with the ridge of the Balkan, and through which the Danube forces its way between Moldavia and Gladova. The line of hot springs begins at Mehadia, in the Bannat, and extends south beyond Nizza in Servia.

A second line may be traced running east and west at the foot of the Balkan. The hottest has a temperature of 162°·5.

A third group exists in southern Macedonia, near Salonichi and Serres. They are mostly sulphureous.

Greece and its Islands.

N. Lat. 41° to 36°. E. Long. 20° to 27°.

Mean temp. not ascertained.

A group of thermal springs at the base of Mount Olympus. The temperature of that at the Pass of Thermopylæ was found by Clark to be 113°.

Hot bath of Venus, east of Corinth.

Korantzia, south of Mount Geranicus, near the Gulf of Corinth, gaseous eruptions and a spring at 87°·8.

At Venetiko, west of Lepanto, a sulphureous thermal spring, called Taphoi (Tombs of Nessus).

Six leagues from Patras, a saline thermal spring, 96°·8.

In the Morea, near Methana, in the ancient Argolis, near the base of an extinct volcano, and in the Archipelago, in the islands of Negropont, (Lelantho, near the ancient Chalcis,) of Milo, Thermia, and Lemnos, are thermal waters*.

Iceland.

N. Lat. 63° to 67°. W. Long. 12° to 25°.

Mean temp. 37°·4 Fahr.

A very numerous class of sulphureous waters, with a high temperature, remarkable for the amount of silica which they contain in solution, is found in that part of the island where trachyte exists and volcanic eruptions at present take place. They are distinguished into three kinds, viz.—

1. Those constantly agitated and in a state of ebullition.
2. Those only agitated at particular periods, being perfectly tranquil during the intervals.
3. Those whose surface is always tranquil and never agitated or boiling.

A second class of thermal waters of a lower temperature, and impregnated only with carbonic acid gas, occurs in the volcanic promontory of Sneefield-Syssel, where igneous operations have ceased†. These only deposit calcareous tuff, not containing, like the former, dissolved silica, although it is remarkable that at former periods they must have done so, as siliceous incrustations exist round about them in the form of tuffs and sinters.

* Consult Virlet, Expédition Scientifique de Morée.

† See Krug von Nidda in Edinb. New Phil. Journ. vol. xxii.

America.

The only thermal waters in the New World which have been examined with any degree of accuracy, are a few of those of the Cordilleras by Boussingault (Ann. de Chimie, 1833), and those of the United States by the scientific men employed in the various geological surveys of that country. The results obtained with regard to the former have been repeatedly referred to in the course of this volume, and many of the thermal springs found in the latter portion of the American continent have been likewise noticed. As however Professor W. Rogers has studied with more particular attention to accuracy those of the mountain region of Virginia, I shall terminate this tabular view with the following statement of the principal particulars respecting them, which he has brought together in the interesting Memoir already referred to, entitled *"On the Connection of Thermal Waters in Virginia with Anticlinal Axes and Faults."*

Name of the spring.	Geological position.	Geographical position.	Temperature.	Gases evolved. 100 cubic inches contain		
				Nitrogen.	Oxygen.	Carbonic acid.
Warm Springs...... Temperature of the place 51°.	In anticlinal axis of Formation II. of Virginia and Pensylvania Reports.	Warm Spring Valley, Bath County.	2 springs: highest 97½° lowest 96	98	2·6	0·75*
Hot Springs......... Temp. 51°.	In the same axis as the above.	Same valley as the above.	8 springs: highest 108 lowest 93	highest 87·5 lowest 75·0	0 6	12·5 19·0
Gap Spring .... Temp. 51°.	In the above axis near the N.W. termination of Formation II.	N.W. of Warm Spring on the road to Bull Pasture.	1 spring 71			
Sweet Alum Springs Temp. 51°.	In the above axis	3 miles S.W. of the Hot Springs.	3 springs: highest 85 lowest 74			
Falling Spring...... Temp. 51°.	Near the S.W. end of the same axis, Formation II.	Near Covington..	1 spring 62			
Sweet Springs...... Temp. 51°.	Anticlinal axis passing into a fault. N.W. side of Formation II.	Sweet Spring Valley, Alleghany County.	5 springs: highest 78 lowest 72	highest 82·0 lowest 62·5	5	13·0 37·5

* With 0·25 of sulphuretted hydrogen.

TABLE (*continued*).

Name of the spring.	Geological position.	Geographical position.	Temperature.	Gases evolved. 100 cubic inches contain		
				Nitrogen.	Oxygen.	Carbonic acid.
Snake Run Springs Temp. 51°.	In the same axis, termination of Formation II.	Near N.E. end of the Sweet Spring Valley.	2 springs: highest 72° lowest 67	77·2	0	22·8
Bath Springs ...... Temp. 52°.	S.E. flank of the anticlinal axis of Capon Mt. in Formation VII.	Warm Spring Ridge, Bath, Morgan Co.	3 springs: highest 74 lowest 72·5	89·7	9·2	1·1
White Sulphur ... Temp. 52°.	In anticlinal axis of Formation VII.	Greenbrier Co...	1 spring 61 to 65			
Wilson's Thermal... Temp. 52°.	In anticlinal axis of Formation VII. N.W. of the axis of Biggs's Mountain.	Near Long's Entry Creek, Botetourt Co.	1 spring... 65			
McHenry's Springs Temp. 53°.	Near the fault bringing Formation II. in contact with Formation XI.	Near North Fork of Holston River, Scott's County.	1 spring... 68			

Professor Rogers also enumerates twenty-seven other springs, situated in the same mountain region, more or less thermal, and often evolving much nitrogen gas, under similar geological circumstances, some of them exceeding the supposed mean temperature of the locality only by three or four degrees, others rising to the same point as those above enumerated.

PART III.

DEDUCTIONS FROM THE FOREGOING FACTS:

WITH REFERENCE

TO THE CAUSES OF VOLCANOS;

THE CIRCUMSTANCES

THAT INFLUENCE THE CHARACTER OF THEIR PRODUCTS;

AND THE

USES THEY FULFIL IN THE ECONOMY OF NATURE.

CHAPTER XXXVI.

GENERAL STATEMENT OF THE VARIOUS THEORIES BY MEANS OF WHICH THE OPERATIONS OF VOLCANOS HAVE BEEN ACCOUNTED FOR.

Two classes of theories, chemical and mechanical. Chemical—Lemery's, Breislac's, Davy's—the latter view shown not to be antecedently improbable. The Mechanical theory founded on the internal heat of the globe briefly sketched.—Necessity, in order to decide to which the preference is due, of ascertaining in what degree either one is competent to afford an explanation of the phænomena.

Having in the former part of this volume brought together such facts with respect to Volcanos, as either my own observations in the countries in which they occur, or the researches of others, were capable of affording me; having also endeavoured to the best of my ability to determine what other natural phænomena are to be regarded as resulting from the same deep-seated Cause; and having presented as detailed an account as my limits permitted, of the consequences of its several manifestations, and of the laws which govern them, I shall next proceed to lay before my readers those general inferences which may appear deducible, either with respect to the cause of the effects above detailed, or the influence exerted by the latter upon those portions of the ancient fabric of our globe, the constitution of which is such, as to imply the operation of internal heat.

With respect to the former of these inquiries (I mean the cause of volcanic phænomena) it must be confessed, that our speculations, from the very nature of the subject, are involved in much uncertainty, since the processes we undertake to investigate are placed beyond the scope of actual observation, and can be conjectured solely from certain of their remote consequences.

In the case before us too, the effects surveyed are often in themselves of such a nature as to render a near and minute

examination impracticable, so that indeed it is chiefly to a review of the minor operations, carried on by a volcano during the stages of its partial intermittence, and of its subsidence into a state of tranquillity, that we are indebted for such data as we possess, upon which to build an hypothesis.

I propose therefore to consider this part of the inquiry, with as much conciseness as may be consistent with a clear exposition of my views; and passing over many hypotheses which have been advanced at various times to explain the nature of volcanos, shall confine myself to the examination of one or two which possess some show of probability, or are supported by the authority of illustrious names.

The theories which have been propounded with the view of accounting for the existence of volcanic action may be divided into two classes; those which assume some chemical process, of which the heat is merely an effect; and those which, assuming the existence of the heat, deduce the other phænomena from its presence.

In the former in short, which I shall henceforth designate as the chemical class of theories, the heat is one of the *consequences*; whilst in the second, which may be called the mechanical, it is assumed as the *prime mover* of all the phænomena observed.

In balancing the merits of these two descriptions of hypotheses, let me in the first place request my readers to divest their minds of all prepossessions that may be entertained against the former, on the ground of their being founded on chemical considerations.

Owing to such prejudices, the scientific world has scarcely, I conceive, allowed itself fairly to appreciate what ought to be the sole grounds of decision in such a case, namely, the claims which each theory puts forth of its competency to explain the phænomena that have been observed. The majority indeed, it is conceived, of those who make the subject of volcanos their study, have allowed themselves to be biased by the authority of certain great names amongst mathematicians,— of men, who chiefly anxious to connect the leading facts with those grand conclusions to which their own speculations have conducted them regarding the internal heat of

the planet, concern themselves but little with any minor details, as bearing upon a science in which they take comparatively but little interest*.

And yet, *à priori*, without any knowledge whatsoever of the nature of the effects themselves, it might, as it would seem, have been with some show of probability conjectured, that so large a mass of matter as that which constitutes the interior of the globe on whose surface we tread,—a mass not, as we have reason to suppose, homogeneous, but consisting of a number of elementary matters endowed with mutual powers of attraction,—should occasionally be found to exert these powers, and should not have entirely settled down into a state of chemical indifference and inaction.

But when we moreover find, that products result from the mechanical movements experienced by the crust of the earth, which are of the very same nature as those obtained from chemical processes artificially conducted, our interest ought to be the more awakened, and our first endeavour should be to refer, at least conjecturally, the effects witnessed to properties of matter with which we are already familiar.

Hence I contend, that when volcanic operations form the subject of discussion, the chemist deserves at least a fair and patient hearing, and that instead, as some seem to do, condemning a theory of volcanos as unphilosophical because "*it smells of the laboratory*," the true philosopher, on a subject so mysterious, will be only too glad to avail himself of all the lights which chemical investigations can offer, and will remain dissatisfied with every proposed explanation, which does not embrace those chemical phænomena which form a part at least, and indeed a very large part, of the problem to be solved.

The theories however which profess to account for volcanic action on chemical principles are very various, and although all agreeing in one particular, namely that of imagining combustion of some kind or other to have caused the heat, differ

* I must except Ampère, who at once a mathematician, a chemist, and a metaphysician of a high order, possessed all the qualifications requisite for appreciating the claims which the chemical theory possesses to our attention. See his Essay in the 'Revue des Deux Mondes,' translated in Jameson's Journal, vol. xviii., for April 1835.

widely as to the material which they suppose to have excited it, coal, petroleum, and sulphur, having all been assumed, at one time or another, as the main agent concerned in the process.

Thus, according to the first and most ancient of these theories, that of Lemery*, volcanos were attributed to the combustion of certain inflammables, similar to those which exist near the surface of the earth, such, for instance, as sulphur, beds of coal and the like; and in order to account for the spontaneous inflammation of these substances, an appeal was made by him to an experiment of his own contriving, which went to prove, that mixtures of sulphur and iron, sunk in the ground, and exposed to the influence of humidity, would give out sufficient heat to pass gradually into a state of combustion, and to set fire to any bodies that were near.

His process was, to mix as large a quantity, as could be conveniently had, of clean iron-filings, with somewhat more of sulphur, and as much water as would make the whole into a firm paste, to bury this in the earth (first wrapping it up in a cloth), and to ram the soil firmly above it. A mixture of this kind in a few hours grows warm, and swells so as to raise the ground. Sulphureous vapours make their way through the crevices, and sometimes flames will appear. Rarely is there any explosion; but when this happens, the fire is vivid —and the heat and flame both continue for some time, if the quantity of materials employed has been great.

Breislac proposed a theory not very different from the above†; he supposes that volcanos may arise from masses of petroleum, collected in underground caverns, and set on fire by some third substance.

He imagines that the presence of certain of the combinations of phosphorus or even of sulphur may give rise to the combustion, and he appeals to the conflagrations that take place in coal mines, as proving that bituminous substances are in fact set on fire by the presence of some body which must be spontaneously combustible.

He shows that petroleum is very abundantly distributed in

* Mém. de l'Académie, 1700.

† Instit. Geolog. vol. iii.

all parts of the globe, and that it is more particularly found in the neighbourhood of volcanos, during the eruptions of which it is often exhaled in great quantities.

This hypothesis however seems to be supported on much the same sort of evidence which has been adduced in favour of the one before alluded to, and is saddled by objections of a similar description; I shall therefore spare myself the trouble of considering it apart, as the observations I shall have to make will apply with equal force to both.

Now the main and insuperable difficulty attendant on these and all other hypotheses which assume the combustion of bodies such as those above-mentioned, is the absence of the products which constantly arise from them under ordinary circumstances, together with the presence of others which could not in such a case be expected.

The carbonic acid, for instance, which would be generated ought to be accompanied with unburnt carbon, with carbonic oxide, and the like; sulphuretted hydrogen could hardly be disengaged in such large quantities from a spot where carbonaceous matters were freely burning; nor could water be so abundantly present without extinguishing the flame, and cooling down the temperature below the fusing point of lava.

In short, it is now generally admitted, that no processes going on near the surface are calculated to produce the phænomena of volcanos; and that if the latter arise from combustion, the materials which occasion it must, in part at least, be of a different description from the combustibles which exist in a natural state within the sphere of our observation, since in order to consume oxygen without substituting for it a corresponding amount of some gaseous oxide, the products must be of a fixed nature, which is not the case in our artificial fires.

Recent discoveries have however convinced us, that the whole of the crust of the earth contains principles, which in their uncombined state are in a high degree inflammable, and which, for this very reason, never occur to us except in union with oxygen. Such are the alkalies and earths, which Sir H. Davy has shown each to contain a metallic basis, a body capable of abstracting oxygen, both from common air and from water, and giving rise at the time to a sufficient extrication of light

and heat to constitute a case of genuine combustion. There must have been a time therefore, as it should seem, when these substances existed uncombined with oxygen even on the surface, and there is no reason to deny, that the process of oxygenation may still be incomplete at those vast depths, where air and water are admitted but slowly or at distant intervals.

Indeed, the late discoveries of Mr. Grove* have rendered it almost demonstrable, that admitting the leading principle for which all the advocates of the mechanical theory contend, namely the existence of a very high temperature pervading at one time all the constituents of our globe,—a temperature sufficient to reduce to a state of fusion at least, if not of volatility, the most stubborn bodies of which we have any cognizance,—a period must have occurred in the history of our planet when those very actions were set up of which we assume the continuance at the present day.

For Mr. Grove, by showing, that at a heat attainable by artificial means, even the attraction between oxygen and hydrogen is overcome, and water resolved into its elements, has rendered it more than probable that at the high temperature supposed to have prevailed in the infancy of our system, all the constituents of the globe must have been mutually diffused, and though thus intermixed, would have continued in a state of perfect chemical indifference one to the other. Now if under these circumstances we suppose the temperature to have sunk down to that point at which the elective attraction of certain of the elements for each other prevailed over the repulsive force of heat, we have a right to infer the occurrence of those very phænomena and the formation of those very products, which our theory assumes to be going on at the present day wherever volcanos exist. There is therefore no antecedent absurdity in imagining that volcanic action may consist in a process of oxygenation, caused, in part at least, by the presence of these substances, and all that seems necessary is to ascertain how far the known phænomena accord with such an hypothesis.

The other class of theories, which begins by assuming the high temperature, and then deduces from it the other phæno-

* Philosophical Transactions, 1846.

mena, seems at first sight to have an advantage over the preceding one, inasmuch as the existence of internal heat may be thought to be in a manner ascertained, whilst that of the alkaline or earthy metalloids, uncombined with oxygen, is at most only probable; and accordingly many have been induced to prefer this mode of accounting for the phænomena, as less hypothetical, and requiring fewer postulates.

They forget, however, that the existence of an internal heat is assumed alike on either supposition, and that the true point of dispute is, whether it can best be explained by the presence of a melted or ignited mass in the interior of the globe, or by a process of oxygenation going on amongst its constituents.

It is indeed a common fallacy to set down *internal* and *central* heat as identical, although a moment's consideration will convince us that the one is a matter of observation, the other purely of inference, and that the only decisive mode of establishing the latter proposition, would be by demonstrating that the nucleus of the globe either is, or at least once was, in a state of fluidity.

Now the only direct argument in favour of the internal fluidity of the globe is deduced from its figure, which has been proved to be that of an oblate spheroid; a form, it is contended, which could not have been imparted to it unless it had been originally liquid, and from whence the advocates of the above hypothesis conceive themselves at liberty to infer, that it is in this state at present.

Neither of these propositions however can be regarded as demonstrated. Sir J. F. Herschel has shown, in his 'Treatise on Astronomy,' that the oblate figure of the globe may only have arisen from its long-continued rotation, this being the point to which, under this condition, it must tend, and which it would ultimately attain, even as its surface is at present constituted.

Professor Playfair, in his 'Illustrations of the Huttonian Theory' (p. 435), has also contended, that if the surface of the earth has been repeatedly changed from sea to land, the figure of the planet must in that case have been at length brought to coincide with its actual one.

But Mr. Lyell has gone further, and in accordance with the views of Poisson shows, that if portions of the interior of

the earth had become from time to time fluid, from chemical causes acting locally, these fluid portions would be impelled towards the equatorial regions in obedience to the centrifugal force, and thus produce an upheaval of the surface in the parts adjoining. Hence the oblate spheroidal figure of the earth affords no independent proof of its original, and still less of its present universal fluidity.

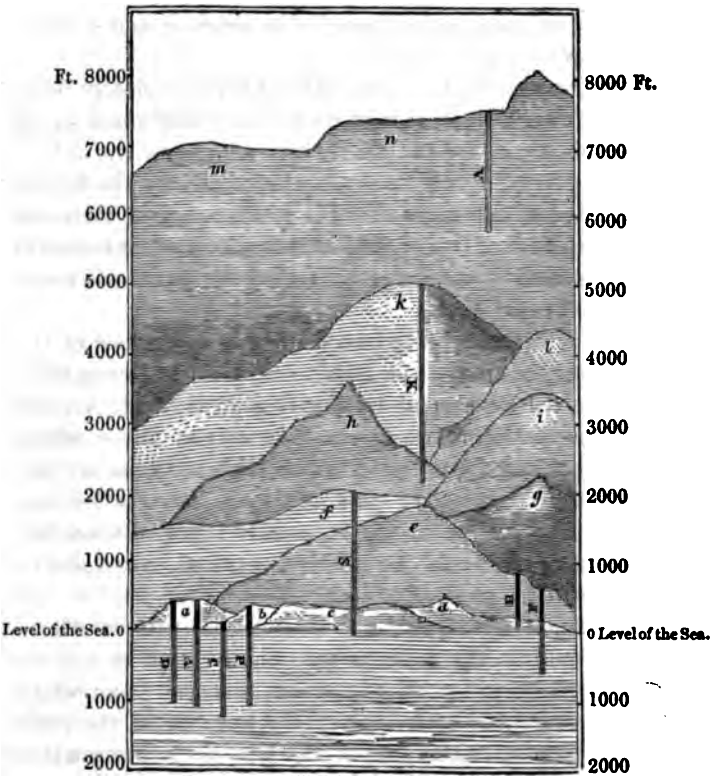
Neither, if we grant the earth to have been originally fluid, is there any direct proof that it would have continued so up to the present time; for the progressive augmentation of heat observed at the slight depths below the surface to which man has penetrated, only proves that the temperature of the crust is higher than that of its superficies, not that it is considerable enough to retain the substances of which the interior is made up in a state of fusion.

There is something indeed very striking in the law of the increasing temperature of the globe, and in the practical illustration of its truth afforded by the fulfilment of M. Arago's prediction as to the thermal condition of the water which would be obtained from the Artesian well at Grenelle, but persons who build upon this and other similar facts are not always sufficiently alive to the extremely small distance beneath the surface to which man has penetrated, compared to the diameter of the globe itself.

As well might a Lilliputian, who with his utmost efforts had only bored into the white of the orange which he had extracted from Gulliver's pocket, conclude that this same tough material pervaded the entire mass, in ignorance of the pulp which it enveloped, as the philosopher who finds warm water at the bottom of his deepest well or mine pronounce, that the temperature goes on progressively to increase from thence to the centre.

The following wood-cut, taken from a larger engraving executed some years ago in illustration of the comparative depth and elevation of remarkable mines in Great Britain and other countries, may render this fact more familiar, by impressing upon our minds the very limited extent within which our observations upon the internal temperature of the globe are at present circumscribed.

COMPARATIVE VIEW OF THE DEPTH AND ELEVATION OF REMARKABLE MINES IN GREAT BRITAIN AND OTHER COUNTRIES.



D. Dolcoath Mine, Cornwall, 1110 ft. A. Wheal Abraham, Cornwall, 1452 ft. C. Consolidated Mines, Cornwall, 1350 ft. (Woolf's Shaft).—P. Ditto (Pearce's Shaft), 1464 ft. B. Wheal Betsy, Devon, 720 ft. F. Wheal Friendship, Devon, 1100 ft. S. Sampson Mine, in the Hartz, 2230 ft. K. Kitzpuhl Mine, in the Tyrol, 2764 ft. V. Valenciana Mine, Mexico, 1770 ft.

a. Mining districts of about 300 ft. *b.* Cornwall. *c.* Highgate and Hampstead Hills, 400 ft. *d.* Shooter's Hill, 446 ft. *e.* Dartmoor, 1800 ft. *f.* Mining district of Andreasberg, about 2000 ft. *g.* Ingleborough, 2361 ft. *h.* Brocken Mountain, 3486 ft. *i.* Snowdon, 3571 ft. *k.* Mountain of Falkenstein, about 5000 ft. *l.* Ben Nevis, 4380 ft. *m.* Table land of Mexico, 7000 ft. *n.* Mountains near Guanuxuata, 7000 to 8000 ft.

Moreover, according to Mr. Hopkins's calculations, the thickness of the solid crust of the globe must at the least approach to 400 miles, and probably does not fall short of from 800 to 1000,—a sufficient proof that the dogma which assumes a regularly increasing rate of temperature from the circumference downwards, can hold good only down to comparatively small depths; for we know of no substance, or combination of substances, which would not enter into fusion at a point far below that which must be reached by the earth at even a few miles' depth according to that assumption.

Indeed, according to the calculations of M. Cordier, we should arrive at the melting-point of iron at a depth not exceeding twenty-four miles, and this too according to the extravagantly high estimate of its fusing-point founded upon observations with Wedgwood's pyrometer.

Thus the present fluidity of the interior of the earth is still more a matter of surmise than its original state of liquefaction.

After all, the proper mode of grappling with the question before us seems to be, not to lose ourselves in conjectures, as to what may by possibility be the condition of the globe at inaccessible depths, but to pass in review the actual phænomena of volcanos, and see whether we can best deduce them from the mere effects of the protrusion of a melted mass of matter, or from a process of combustion, originating in materials which may still exist in an unoxidized state below. In order however to determine this, it will be necessary to consider at some length, first, the geographical situation of volcanos; secondly, the character of the substances evolved by them in a gaseous state, and of the products resulting; and thirdly, that of the lavas and other matters ejected in a solid or liquid condition: from whence we shall be led on to examine, fourthly, the depth at which volcanic action is seated; and lastly, the mode in which mountain masses and extensive tracts of country are built up of the materials that have resulted from the operation of internal fires.

CHAPTER XXXVII.

GENERAL INFERENCES RESPECTING THE LAWS OR CONDITIONS OF VOLCANIC ACTION.

Local distribution of volcanos—in lines—and in groups—their general proximity to the sea.—Aëriform fluids evolved.—Bodies not permanently elastic which are evolved as vapours.—Bodies in a solid state ejected—viz. 1st, lavas, their chemical characters—2ndly, loose fragments thrown out. Relation of these bodies to trachyte—trachyte whence derived.

Depth at which volcanic operations proceed. Constitution of a volcanic mountain—mode of its formation. Production of a crater—by eruption—by elevation.—Proofs of the elevation of volcanic mountains—1st, from their own internal structure—2ndly, from the existence of domes of trachyte—3rdly, from the continuous sheets of volcanic matter overspreading large districts—4thly, from the testimony of eye-witnesses in the case of Santorino—Unalaschka—Graham's Island—Monte Nuovo—Jorullo, &c.

Statement of Von Buch's views with regard to craters of eruption and of elevation.

VOLCANOS are said by Von Buch, either to occur scattered at certain distances along particular lines of country, or else to be united in clusters around some common centre.

The former he calls linear, the latter central volcanos; and whilst he regards the linear as being in general produced in the direction of the fissures caused by the igneous operations of a former period, along the tracts near which the primary ranges of mountains have been upheaved, he considers the central as taking place in all kinds of positions over the earth's surface, however much detached they may be from any of those leading systems of elevation, wherever the force which has been set in motion by volcanic agency has been able to overcome the resistance opposed by the superincumbent rocks. In the former case the direction taken by the volcanic forces is determined by the previous configuration of the country; in the latter they manifest themselves without any reference to the nature of the pre-existing rocks.

It may perhaps be doubted whether even the central volcanos enumerated by Von Buch do not in some instances at least admit of being referred to some common system, as Vesuvius, Lipari, and Etna might be regarded as the points of greatest intensity in a volcanic band stretching longitudinally along the Peninsula. There can be no question however, that the law which he has laid down with regard to the tendency of volcanos to burst forth along certain lines of country rather than in others, holds good very generally, and that many such groups may be enumerated; such as that already pointed out as extending across the Greek Islands; that stretching across Mexico; and still more remarkably the one, which, beginning on the coast of Arracan, and manifesting itself at Barren Island, in the Bay of Bengal, may be traced along the islands of Sumatra and Java, thence to the Philippines, and perhaps even to the Kurule Islands and to Kamtschatka. The linear direction, therefore, of certain volcanic formations cannot be doubted; and the only question is, whether it prevails universally, or characterises, as Von Buch conceives, one particular class only of burning mountains.

Another remarkable feature in the distribution of volcanos is their proximity to the sea; in proof of which it may be sufficient to remark, that out of a catalogue of no less than 163 active vents enumerated by M. Arago* as occurring in various parts of the known world, all, excepting two or three in different parts of America, and about the same number, of which we possess very imperfect information, in Central Asia, are within a short distance at least of the ocean†.

* Annuaire pour l'an. 1824.

† The ancients remarked the same thing with regard to volcanos. Thus Macrobius in Somn. Scip. lib. ii. chap. 10, says, "Ignem æthereum physici tradiderunt humore nutriri;" and Justin, lib. iv. sub initio: "Accedunt vicini, et perpetui Ætnæ montis ignes, et insularum Æolidum, veluti ipsis undis alatur incendium. Neque enim in tam angustis terminis aliter durare tot sæculis tantus ignis potuisset, nisi humoris nutrimentis aleretur." He therefore supposes the waters to be sucked up by Charybdis, and thence transmitted to the volcano which they nourish. "Eadem causa etiam Ætnæ montis perpetuos ignes facit. Nam aquarum ille concursus raptum secum spiritum in imum fundum trahit, atque ibi suffocatum tamdiu tenet, donec per spiramenta terræ diffusus, nutrimenta ignis incendat."

So general indeed is this law, that Humboldt thinks it worthy of remark, that the volcano of Tolima is forty leagues inland,—a distance truly insignificant when we recollect that several portions of the great continents of Asia, Africa and America lie several thousand miles distant from any ocean.

It is even found, that the very volcanos which constitute the cases excepted, when examined, tend to confirm the rule, being so situated that their connexion, either with the ocean, or with inland seas that may supply its place, becomes a matter of fair inference. In proof of this we need only refer to the descriptions already given of Jorullo, from which it appears that, distant as this mountain may be, both from the Atlantic and Pacific Oceans, it is nevertheless connected with one or both through the medium of a chain of volcanic eminences; constituting, to use an expression of Humboldt's, one single swollen mass, of which these mountains are to be regarded only as the several chimneys (page 489); and even the volcanos of Tartary, whose existence in an active condition is however very problematical, might be in proximity to some of those extensive salt lakes which seem to abound in the depressed portion of Central Asia.

Thus even the few cases which have been brought forward as exceptions to the general rule, appear, when examined, to enter into it, so far as relates to the probable connexion they denote with deep seas or lakes; whilst the occurrence of by far the majority of active volcanos in islands and maritime tracts, and their entire absence from many extensive continents, may convince us that the processes concerned are at least greatly promoted by such a position, and in their intensity bear a certain relation to the more or less ready access to them of water.

And although extinct volcanos seem by no means confined to the neighbourhood of the present seas, being scattered often over the most inland portions of our existing continents, yet it will appear, that at the time at which they were in an active state, the greater part were in the neighbourhood either of the sea, or of those extensive salt or freshwater lakes, which existed at that period over much of what is now dry land. This may be seen either by referring to Dr. Boué's Map of Europe, or to that published by Mr. Lyell in

the recent edition of his 'Principles of Geology' (1847), from both which it will become apparent that at a comparatively recent epoch, those parts of France, of Germany, of Hungary, and of Italy, which afford evidences of volcanic action now extinct, were covered by the ocean.

Instead, therefore, of these being brought forward as exceptions to the generality of the rule, the cessation of such action, now that the water has left their neighbourhood, seems to furnish a confirmation of its truth.

Nor must we forget that remarkable fact to which allusion has been already made in Chapter XVIII. relative to the constant flow of sea-water into the earth in the island of Cephalonia, and that in a country subject to earthquakes, and not remote from actual volcanos,—a proof as it should seem that sea-water does find its way into the interior of the earth, as indeed it is reasonable to expect would be the case, if we only assume the existence of any cracks or fissures beneath the bed of the ocean, since the enormous pressure exerted by a body of water four or five miles in depth could hardly fail to inject some portion of its contents through the minutest crevices that might occur beneath it.

Thus volcanos may be among the appointed means for bringing back to the surface the water which finds its way into the interior of the globe, as will be pointed out when the final uses of the mysterious agent under consideration come before us.

I have next to consider the ordinary products of volcanic operations, and shall begin by noticing the aëriform fluids evolved, regarding them as in a manner the prime movers of the effects we witness,—the agents, which have elevated, as there seems reason for believing, from time to time many isolated mountains and even extensive tracts of land above the level of the waters, and by whose mighty power operating in a more regulated and continuous manner are propelled from the bowels of the earth those solid matters afterwards to be described, which, settling round the brim of the orifice from which they have established for themselves an issue, grow at length into the form and dimensions of an ordinary crater of eruption.

Steam* is also emitted, sometimes for ages together, from fissures called "stufas," on the flanks of many extinct as well as active volcanos; thus supplying us with a confirmation of the dependence of volcanic phænomena upon the presence of water.

The permanently elastic fluids commonly given out are, muriatic acid, sulphuretted hydrogen, sulphurous acid, carbonic acid, and nitrogen.

We have seen indeed in some instances, as in New Zealand, that a volcano has gone on for years vomiting forth from its crater nothing but steam, proving as it were an intermediate link between a thermal spring, and a permanent vent like that of Vulcano, which, besides water, emits also several kinds of gaseous matter.

Of these the first, muriatic acid, seems to be generated during almost all the phases of volcanic action; for although some have attempted to establish a class of volcanos to which the production of muriatic acid was peculiar, yet it would appear that there were none from which this gas is not in greater or less quantity disengaged†.

Thus it has been detected by Sir H. Davy, not only issuing from the flanks of Vesuvius soon after the eruption of 1815, but likewise from the same mountain whilst in a more quiescent condition in 1824.

It was also found by myself, both in 1834 and 1845, at the crater of Vesuvius, and in the former year issuing from the recently-erupted lava, in the crevices and pores of which it was

* Sir H. Davy, in his Memoir on Vesuvius, justly remarks, that it is very easy, even at a great distance, to distinguish between the steam disengaged by one of the craters, and the earthy matter thrown up by the other. The steam, he says, appeared white in the day, and formed perfectly white clouds, which reflected the morning and evening light of the purest tints of red and orange. The earthy matter always appeared as a black smoke, forming dark clouds, and in the night it was highly luminous at the moment of the explosion.

† Is not this what Livy refers to, when he speaks of clouds of wool being seen to rise from the ground at Privernum (now Piperno)? "Priverni lana pulla terrâ enata," l. xlii. c. 2. Julius Obsequens notices a similar phænomenon at Præneste (Palestrina), c. 140 and c. 89. It is probable that the evolution either of muriatic acid or of muriate of ammonia gave rise to this mistake.

entangled. I moreover discovered it in 1826 in the vapours given off round the crater of the island of Vulcano, round that of Etna whilst dormant, and in that of the Solfatara of Puzzuoli. It has been detected also in the volcanos of Iceland; in those of Java, at Mont Idienne; and amongst the South American ones, at Puracè, accompanied in both these latter cases with a predominant proportion of sulphuric acid; nay, it has even been found, as we have seen, in an uncombined state, pervading the trachytic rock of the Puy de Sarcouy in Auvergne.

Of the gaseous compounds of sulphur, one, the sulphurous acid, appears to be predominant chiefly in volcanos possessing a certain degree of activity; whilst the other, sulphuretted hydrogen, has been most frequently perceived amongst those in a dormant condition.

Thus sulphurous acid has been observed proceeding in large quantities from the craters of Etna and Vesuvius*, and even from that of Vulcano in the Lipari group, whilst sulphuretted hydrogen is commonly present at the Solfatara of Puzzuoli, on the skirts of Etna near Jaci Reale, and in many hot springs connected with dormant volcanic action both in these regions and elsewhere.

Not that we are obliged to suppose sulphurous acid to be entirely absent in the latter cases, or sulphuretted hydrogen in the former; for as these two gases, when they meet, decompose each other, forming water and depositing sulphur, it is reasonable to expect, that merely the portion of either which exceeds the quantity necessary for their mutual decomposition will escape from the orifice, so that the gas that actually appears indicates only the predominance of the one, and not the entire absence of the other.

As to the nature however of the gases which issue from the crater of a volcano whilst in a state of activity, our knowledge is of necessity conjectural, although some advance has of late been made towards its determination by having the question relating to the evolution from the *focus* of the igneous action of some kind of inflammable gas, which must in all probability consist either of simple hydrogen or of certain of its

* Not however generally, for at present sulphur seems a very rare product.

combinations, at length set at rest, so far as the testimony of intelligent eye-witnesses can justify us in so regarding it. It had long been disputed, whether the appearance of flames observed during eruptions was anything more than the reflection of the light produced by the ignited surfaces of the ejected masses, and whether the emission of inflammable gas had anything to do with that phænomenon.

Spallanzani altogether denies that it has, and Gay-Lussac, who with Humboldt and Von Buch visited Vesuvius in 1805, whilst in a state of activity, could never perceive any inflammation of gaseous matter at that period. Negative however must not be set against positive evidence, especially in a case like the present, where it is easy to assign reasons why the production of flames should be only an occasional, and not a constant phænomenon. Hydrogen and its compounds, as is well known to chemists, will not inflame when either muriatic acid gas or steam is intermixed with them in certain proportions. Now both these are abundantly evolved during most volcanic eruptions, and consequently it is very possible that a gas which was by itself inflammable, might escape into the open air without combustion, in consequence of the presence of one or other of the above principles.

But that the actual inflammation does occasionally take place, was averred by Sir Humphry Davy as observed by himself at Vesuvius during a small eruption, and by M. Elie de Beaumont as witnessed at Etna; whilst lately we have received a more circumstantial account of three several occurrences of this kind in the years 1833 and 1834, which fell under the observation of Professor Pilla of Pisa.

"On the night of the 2nd of June 1833," says the Professor*, "I was within the crater of Vesuvius in order to observe the phænomena of an eruption, which was approaching its close. In the centre of the crater there was one of those cones of scoriæ which are formed and disappear with such marvellous rapidity: it was the largest one I had ever observed, and there was on its summit a large funnel-shaped aperture, through which the explosions took place. At the moment of which I speak they had become less frequent, and this circumstance made me desirous to mount upon the cone, in hopes of

* See his memoir in the 'Comptes Rendus,' translated in the 'Edinburgh New Philosophical Journal' for October 1843.

observing what would take place better than I had been able to do on former occasions, when the smoke, ejections of stones, and other circumstances prevented my seeing distinctly into the *orifice*.

"At the moment of explosion I ascended to the edge of the cone, along with my courageous guide, who shared in my curiosity to observe the appearances. The interior of the opening was almost entirely free from smoke; a small quantity only issued from different points in the walls. This fortunate circumstance enabled me to see very distinctly all the parts of the crater, and everything that was going on there. The bottom of the funnel was open; it lay immediately under my eyes, at a depth of about eighty metres; its circumference was nearly twenty yards; the whole of its burning interior was visible. The view of the phænomena which accompanied the explosions was inexpressibly magnificent. They consisted of the following:—

"A loud subterranean noise, and a violent shock, announced the explosion; immediately after, and almost at the same time, the mouth opened and made a discharge, with a noise resembling that of a discharge of cannon. A column of black and fuliginous smoke issued with great violence, and there was thrown up, with the rapidity of lightning, an enormous torrent of inflamed gaseous substances and burning stones, which fell back like hail, for the most part into the gulf, but partly outside of it. Though overpowered by the grandeur of the spectacle, I did not fail to observe the column of flames which accompanied the explosion. It rose to the height of four or five yards, and then disappeared among the volumes of smoke, so that a person whose eye was on a level with the edge of the gulf could not have seen it. Hence it is that the existence of flames has been so confidently denied. The flame which I observed was of a very decided violet-red colour.

"It was very obvious that the gas which produced it became inflamed by contact with the air, because it burned only at the circumference, and in the interior was obscure, presenting on a large scale what may be seen in a lamp on a small one. After the explosion and fall of stones had terminated, another very remarkable phænomenon was perceived. Insulated flames, disposed in a very picturesque manner, remained in the bottom of the gulf, moved around its mouth, and flickered very slowly about the walls of the funnel; an appearance which might be compared—*si licet maxima componere minimis*—to the flame of alcohol burning in a crucible. The beautiful violet colour of the flame was then easily distinguished; a faint smell of hydrogen accompanied these phænomena. I continued for a quarter of an hour gazing on this enchanting spectacle, and during that time

saw five explosions always accompanied by the same appearances; I would have remained longer on the same spot, had not the last of these explosions, which was much more violent than any of the preceding, compelled us hastily to retire.

"In the month of June in the following year, 1834, Vesuvius was in a state of eruption, and on the evening of the 7th I visited the crater. The exterior cone was throwing up stones with such violence that it was impossible to approach it. A current of lava was spouting out through a fissure at its base. Quite near to me, there was an elevation of a longitudinal form, which bore eight small cones, or rather eight large tubes of lava, open at the summit, and throwing out gas and steam with a whistling noise that was quite deafening, and which might be compared to that caused by opening the valves of a high-pressure steam-engine. Favoured by the darkness, we saw that these actions were accompanied with beautiful conical flames, which issued from the tubes with a violence that might be in some measure compared to a flame increased in intensity by a blow-pipe. The length of these flames was from three to five inches, and their diameter at the base about an inch and a half; they burnt with a beautiful greenish colour, like alcohol holding boracic acid in solution; such a colour would very likely be produced by the chloride of copper accompanying the gaseous substances. The smoke which escaped from the openings in the cones had an intolerable smell of muriatic acid; sulphuretted hydrogen was not perceptible.

"This was the second time that I observed flames in the crater of Vesuvius, and I saw them in company with my esteemed friend M. Ravergie of Paris, who was my companion in this expedition.

"I saw very beautiful flames from Vesuvius, for the third time, during the great eruption in August 1834. An opening was formed in the volcano at its eastern base, and a great current of lava was thrown out, which spread over the fertile lands of Ottajano. In the place where the lava spread, two elevations were formed, which supported twelve small cones,—kinds of *Hornitos*,—all of which were in great activity, and produced noisy explosions.

"One of these cones, which appeared the most active, and which I could approach near, notwithstanding the smoke it spread on all sides, was emitting by its opening, besides quantities of stones, a bright flame of a reddish-white colour, which came forth with great violence, and rose to the height of three yards. The jet was continuous, like the flame from a high furnace urged by bellows. The smoke was charged with muriatic acid, and in a few moments it enveloped Professor Tosone of Milan and myself in such a manner that we were nearly suffocated.

"I never had the good fortune to observe flames on Vesuvius in so distinct a manner as on these three occasions, nor have I ever seen them on the surface of a current of lava far from their source, but my friend M. Maravigna assures me that he observed them on a current from Etna during the eruption of 1819."

From these observations Professor Pilla concludes—

"1. That flames never appear at Vesuvius but when the volcanic action is energetic, and is accompanied with a development of gaseous substances in a state of great tension; they do not appear when the actions are feeble.

"2. Their appearance always accompanies explosions from the principal mouth; only they cannot be observed except under favourable circumstances.

"3. They likewise show themselves in the small cones in action, which are formed in the interior of the crater, or at the foot of the volcano.

"4. Finally, they are not visible except in the openings which are directly in communication with the volcanic fire, and never on the moving lavas which are at a distance from their source."

With regard to the nature of the gas which produces these flames, the Professor believes that it was not sulphuretted hydrogen, but hydrogen in a state of purity. This he infers from the odour, which, except in the first instance, was not that characteristic of the former gas, but corresponded more nearly with the latter, and likewise from its colour, which in the third instance was like that of pure hydrogen.

But whether we regard the gas evolved as simple hydrogen or as one of its compounds, the inference to which its presence conducts us is precisely the same; and when we consider the enormous amount of sulphuretted hydrogen constantly disengaged from many thermal springs indisputably of volcanic origin, as well as the vast accumulations of sulphur derived from similar emissions of this gas that must have taken place antecedently, there seems no reason to doubt, that hydrogen may have been also a product of the more intense phases of volcanic action, either in one form or the other, according as sulphur happened to present itself or not.

Carbonic acid appears to be chiefly found in volcanos that have become extinct, and when occurring in those considered active, it is at a time when they are not in a state of eruption. It is also found emitted more commonly at the foot and in the

neighbourhood of volcanic mountains, than from their craters, or at the points of their most vehement action; so that it may be viewed perhaps rather as one of the consequences of a long-continued operation upon the contiguous rocks of the heat produced by volcanic processes, than as the direct effect of those by which that heat is occasioned.

The last of the gases mentioned, nitrogen, has been already sufficiently alluded to: from the observations hitherto made, it would seem to be for the most part the result of languid volcanic action, and hence to be an almost constant concomitant of thermal waters; but it is probable that when the gases evolved from active volcanos have been scrupulously examined in a greater number of cases, it will be noticed much more commonly as occurring amongst them; since Sir H. Davy detected it in Vesuvius, and his brother, Dr. John Davy, in the gas given off by the new volcanic island near Sicily, in both cases accompanied with less than the usual proportion of oxygen.

Other substances are often disengaged from volcanos as vapours, but condense round its exterior either in a liquid or a solid condition.

Such is the petroleum found by Breislac at the foot of Vesuvius, in the Val di Noto in Sicily, amongst the extinct volcanos of ancient Latium and Auvergne, on the spot now occupied by the Dead Sea, the site of the ancient eruption recorded in the Book of Genesis, and in many other localities. Such also is the sulphuric acid, which has been hitherto noticed chiefly amongst extinct volcanos; as for instance in a stream issuing from that of Puracè between Bogota and Quito, in one derived from Mont Idienne in Java, and probably in the rocks connected with the languid operations proceeding about Radicofani in Tuscany.

Its occurrence is satisfactorily explained in a recent paper* by M. Dumas. He shows, that when sulphuretted hydrogen at a temperature above 100° Fahrenheit, and still better when near 190°, comes into contact with certain porous bodies, a *catalytic action*, as it is called, is set up, by which water, sulphuric acid and sulphur are produced. Hence probably the

* Annales de Chemie, Dec. 1846.

vast deposits of sulphur associated with sulphates of lime and strontian which are met with in the western parts of Sicily.

The solid substances sublimed by volcanos are,—1. Boracic acid, found in the crater of Volcano and the Lagunes of Tuscany, which, though it remains fixed in our furnaces, appears to be evolved in vapour by these volcanos. This circumstance however is probably connected with the presence of steam, for I have myself found by experiment, that if aqueous vapour be passed over powdered boracic acid, it carries a portion of the solid matter along with it, even though the latter be vitrified. Nor is this a mere mechanical effect, such as happens when a current of steam meets in its passage with finely powdered lime or magnesia, for traces of the boracic acid were detected, even though the substance had been inclosed in a tube, closed at both ends by platina foil perforated with very minute apertures for the passage of steam; whereas when the earths were introduced into the same kind of apparatus, not a particle of them was carried along.

2. Muriate of ammonia seems to be very copiously disengaged during certain eruptions, as by that of 1780 at Etna, and by Vesuvius commonly. I collected it abundantly in 1834 in beautiful orange-coloured crystals, disengaged from the cracks and crevices of the same fluid lava which had been emitted three months before. Its colour is attributable to the presence of a small quantity of iron.

3. Specular iron ore, probably sublimed in combination with chlorine, which latter principle may become separated, on its coming into contact with the atmosphere, by means of the heat, water, and oxygen of the air.

4. Muriate of soda, the most abundant, as well as the most universally present of them all, being exhaled more or less from almost all volcanos, and present even in their lavas, according to Monticelli, who obtained more than nine per cent. of it by simple washing, from that which issued from Vesuvius in 1822.

I do not include among these sublimations the deposits of sulphur, or the sulphurets of iron, copper, arsenic, and selenium; still less the various sulphuric salts found efflorescing around the spiracles of all volcanos.

The sulphur, which seems to be of such common occurrence

where volcanic operations are going on, is evidently derived, either from the mutual decomposition of sulphurous and sulphuretted hydrogen gases, or from the catalytic action exerted upon the latter gas by porous bodies assisted by a certain temperature. We know at least of no well-authenticated case of its sublimation in an uncombined state from any volcano, and analogy would lead us to extend the same inference to the compounds of sulphur with arsenic and selenium that occasionally accompany it.

The sulphates of lime, alumina, iron, magnesia, and soda, which so frequently encrust the surfaces of recently ejected masses, or the fissures of volcanos in present action, are evidently produced owing to the affinity exerted by the sulphuric acid, which has been produced in the way described, for those alkaline and earthy bases with which it may have come into contact.

The substances hitherto noticed, in whatever condition they may present themselves to the eye of the observer, have evidently either been disengaged from the volcano as gases, or at least have resulted from its gaseous products; but we have next to consider those which have been thrown out in a solid or a liquid state from the crater, not having become, like the former, volatilized by the action of the heat.

These may be divided into such as have undergone a complete change from the process, amongst which we comprehend lavas and loose ejected masses of similar composition; and such as are thrown out, either unaltered, or at least retaining enough of their original characters to be identified with some one or other of the existing rocks.

Beginning with the former class of substances, I shall first state their chemical and afterwards their mineralogical characters.

Lava, when observed as near as possible to the point whence it issues, is, for the most part, a semifluid mass of the consistence of honey, but sometimes one so liquid as to penetrate the fibres of wood*. It soon cools externally, and therefore exhibits a rough uneven surface; but as it is a bad conductor of heat, the internal mass remains liquid long after the

* Fleurian de Bellevue sur l'Action des Volcans.

portion exposed to the air has become solidified*. The temperature at which it continues fluid is considerable enough to melt glass or silver†, and has been found to liquefy in four minutes a mass of lead of such a size, as, when placed on red-hot iron, to require double that time for entering into fusion‡.

Stones of a spongy nature, pumices probably, melted when thrown down into the lava of Vesuvius; that of Etna is said to have effected the same§; and a current, which proceeded from an Icelandic volcano, is stated to have fused every kind of hard stone that came in its way.

On the other hand, masses of limestone have been taken out from the midst of lava with no signs of fusion upon them, and even with their carbonic acid undiminished; whilst the houses of Torre del Greco, and of other villages which had been enveloped in liquid lava, remained unaffected by it. When bell-metal was submitted to the Vesuvian lava of 1794, the zinc was separated, but the copper continued unaltered‖.

Sir James Hall, in his memoir on Whinstone and Basalt, has presented us with a table of the relative fusibilities of seven specimens of whin or basalt from the neighbourhood of Edinburgh, and of an equal number of lavas from various European localities; from which it appears, that when converted into the state of glass, they became softened at a temperature from 15° to 21° of Wedgwood, or 3027° to 4197° of Fahrenheit. Whilst in a crystalline state the same ingredients continued solid at this temperature, but became soft at one varying from 28° to 55° of Wedgwood, or from 4717° to 8227°, a heat inferior to that of a common glass-house.

With this statement regarding the melting-point of ignigenous products, the chemical composition which appears to belong to them is in complete accordance.

* That of 1822, some days after it had been emitted, raised the thermometer from 59 to 95 at a distance of twelve feet—three feet off, the heat produced greatly exceeded that of boiling water. (Monticelli, Storia di Vesuv.)

† Breislac, Voy. dans la Camp. i. p. 279.

‡ Spallanzani, b. 4. p. 3.

§ Ibid. b. 4. p. 8, and Fazzello as quoted by Spall. p. 11.

‖ Breislac in *loc. cit.*

Thus it may be seen, by turning to the second chapter of this volume, that lava consists in general of one of those species of the felspar family which contain one atom of silica united with one of alumina, namely either labradorite, anorthite, or ryacolite, most commonly the first, and that with this is associated the mineral called augite—a silicate of lime, magnesia, protoxide of iron or of manganese. Now neither of these minerals are of a very infusible character, but in consequence of the affinity subsisting between the silica they contain and the respective bases, yield readily to the heat of an ordinary blast-furnace, as might indeed be expected from the analogy of their composition to that of artificial glasses*.

Nevertheless there are circumstances which have induced certain naturalists to adopt quite a different view of the nature of lavas, and to imagine them to owe their fluidity, not to the intensity of the heat, but to the presence chiefly of some solvent or flux.

This opinion was originally broached by Dolomieu, who founded it upon an assumption, now admitted to be erroneous, namely that the crystals of augite and hornblende which lava contains, existed antecedently to the fusion of the mass, and were not produced in consequence of the latter being brought into a melted condition. Hence he necessarily concluded, that the lava could only have been subjected to a degree of heat inferior to that at which such crystals would become fused.

Finding therefore sulphur to be exhaled from certain lavas, he imagined this to act as a flux to the other substances, and accounted for the difficult fusibility of the mass when once cooled, from the escape of the sulphur originally present. Now the existence of sulphur in lavas has been asserted by some and denied by others: if it ever is present in them it must be in the state of sulphuretted hydrogen, detained, as muriatic acid is known to be, within the pores of the lava by a kind of adhesive affinity, but slowly disengaged from it during the process of cooling. Whether however it occurs or not, there seems no necessity for attributing to its presence the fusion of

* According to Saussure, 'Journal de Physique,' an. 2, felspar melts at 70° of Wedgwood, basalt at 76°, and hornblende at about 100°.

the mass, when, as we have seen, the composition of the latter alone sufficiently accounts for this circumstance.

It must in any case be disengaged very soon after the melted matter has been ejected, for no sulphurous vapours are perceived to issue from a lava-current of old standing, even though it may continue internally fluid; and it is well known that sulphur forms no part whatever of the composition of lavas, and can therefore only be mechanically mixed with them.

An English geologist some years ago* brought forward a modification of Dolomieu's theory, by supposing water to act the part which the latter attributed to sulphur; and although we are compelled to reject his theoretical views on this subject as utterly inconsistent with known chemical principles, yet they tend to corroborate those facts which I have myself recorded with respect to the existence in lava of certain volatile matters, which are copiously disengaged from it in the state of vapour. These would appear to have been confined by the pressure of the superincumbent mass, until its gradual cooling caused fissures by which they were enabled to make their escape, and perhaps the influence of pressure may have been assisted by some kind of adhesive affinity between them and the other constituents†. From their presence in a gaseous form, pent up within the interior of the mass, may possibly have arisen those caverns and vaults which exist in many lavas whose thickness is considerable, such as certain of those in Iceland.

All writers admit that various salts are emitted from the surface of recent lava which are never found amongst its constituents; and if these are sublimed, as appears to be the case, by the heat, the same may also happen in the case of those other more volatile matters, whose extrication from lava is vouched for on respectable authority.

The loose fragments ejected from the crater differ but little in mineral composition from the continuous streams of lava, but they are generally of a more cellular and porous aspect, not uncommonly fibrous, and consequently more brittle and incoherent. They also more frequently present that vitreous

* Mr. Poulett Scrope in his work on Volcanos.

† See this point discussed in my memoir on the Eruption of Vesuvius in 1834, Phil. Trans. 1835.

appearance which is the effect of sudden cooling, and vary in size from masses many tons in weight to a fine and impalpable powder.

There seems therefore good reason for suspecting that all those volcanic products which we have just been considering, in whatever form they may have issued from the volcano, are allied to the rock denominated trachyte; being either derived from it, or containing in common with that rock, felspar as one of its essential ingredients. Indeed it has been often found, that in many places where the structure of a volcanic mountain has chanced to be exposed, the lowest in the series of formations that present themselves to the eye is of a trachytic nature, and that the strata superincumbent seem to show a resemblance to that rock, more or less close in proportion to their contiguity to it*.

Trachyte also is a rock of such universal occurrence in volcanic countries, and so abundant in those in which the action is of the most remote date and has taken place on the most extensive scale, that it seems to be natural to derive from it the lavas subsequently ejected, regarding them merely as so many modifications of this original material, more or less changed by the longer continuance of the heat, or by the admixture of other matters.

But considering the peculiar characters and composition of trachyte, as well as the circumstance of its being limited to countries that appear to have undergone the action of volcanic fires, we can hardly regard it as a substance which makes a part of the original constitution of the globe, and shall be disposed to set it down as itself a product, although a primary one, of the fusion of other kinds of rock. Of what nature this latter may consist, will perhaps be determined if we examine, first, with what particular descriptions of rock trachytes are most connected in point of situation; and secondly, to what they present the nearest resemblance in mineralogical and chemical composition.

The former inquiry will lead us to consider, in the first instance, the nature of those ejected masses which appear to belong to the contiguous rock formations, and not to be pro-

* See especially the chapter on the Canary Islands.

ducts of those igneous operations to which their ejection has been owing.

Among these we read of no substance bearing the slightest resemblance to the constituents of secondary or tertiary strata, but of many which may with the greatest probability be referred to rocks of a granitic character.

Thus at the Puy Chopine in Auvergne, granite is found intermingled with the trachyte and greenstone, thrown together in confusion, as if the whole was elevated at one time before the rock had undergone an entire change from the process. In the lavas of the Vivarais, in those of the Rhine, and in other localities, imbedded masses have been met with having much the appearance of an altered gneiss or granite. Humboldt mentions his having found, in the midst of the new volcano of Jorullo in Mexico, white angular fragments of syenite, composed of a small portion of hornblende, with much lamellar felspar; Gemellaro discovered a mass of granite containing tinstone amongst the ejected masses of Mount Etna; and the same rock has been detected amongst the trachyte of the Ponza Islands by Mr. Scrope, and in the lava of Vesuvius by Dr. Thomson of Naples.

Mica-slate has, in one instance, been found ejected from Vesuvius, and various granular limestones of a dolomitic character are met with amongst the masses derived from the old crater of Vesuvius, which lie accumulated in the Fossa Grande and other hollow ways on the slope of the volcano. It must be remarked however that these latter are never imbedded either in the lavas or in the volcanic masses ejected, so that they do not stand in the same relation to them as the granitic masses do which have been above enumerated.

With regard to the formations in which trachytic rocks, or to speak more generally, volcanos, usually appear, great discrepancy seems at first sight to exist.

Thus, to begin with the Rhine, the formation on which the trachyte of the Siebengebirge rests, and among which the volcanos of the Eifel have arisen, is a clay-slate belonging to the Silurian series; in Auvergne, the rocks of Mont Dor and of Clermont either rest immediately upon granite, or are separated from it only by a tertiary deposit, whilst those of Cantal are incumbent on mica-slate. In Hungary the rock under-

neath is a porphyry associated with syenite, clay-slate, &c., and referred by Beudant to the transition series; in Transylvania, according to Boué, the trachytes lie near the mica-slate and gneiss, with which are masses of syenite and marble; whilst in Styria the rock most immediately surrounding the little trachytic formation of the Gleichenburg is gneiss.

In Italy the case is somewhat different; yet, though the trachyte of the Euganean hills rises from beneath chalk, we have reason to believe that primary rocks lie at no great depth beneath, as they are found near Schio, and support the alternations of volcanic and neptunian deposits in the Braganza.

Humboldt states, that the rock which supports the volcanos of the New World is generally what he calls a transition porphyry, and more rarely granite or syenite; and Von Buch reports, that the last-named rocks appeared as the lowest of those uplifted strata which surrounded the crater of the island of Palma and other of the Canaries.

Now, although the preceding enumeration indicates such a variety with regard to the position of volcanic formations as may seem at first sight to baffle all general conclusions, yet when we consider that, in the majority of instances, the rocks have been referred either to the primary or to the most remote palæozoic series, and that in the remaining ones, the latter were at a depth far less considerable than that at which we shall afterwards find reason to conclude that the volcanic force itself resides, it may not be unfair to presume that volcanos have universally broken out amongst the older formations, or those most near to the nucleus, whatever that may be, of the globe.

It is obvious indeed, that in those cases in which volcanos have appeared in the midst of primary rocks, we cannot presume the seat of action to reside amongst those of a later date, but that the converse does not hold good; so that if we only admit that any certain position is to be assigned to these products, a single case of their occurrence in the midst of older formations would overturn every inference that can be derived from observing them to emanate from strata of a more recent date.

If, then, there be reason to conclude that the substance

which has supplied the materials ejected by burning mountains, or which constitutes their internal nucleus, be derived from granitic rocks, a strong argument will be afforded in favour of the great depth at which those operations must have been seated that have given rise to the effects we witness.

This inference indeed is greatly strengthened by a consideration of the phænomena attendant on an eruption, the general tenor of which plainly denotes, that the focus of the action is situated at a depth at least as great as that to which granite may be supposed to extend.

I do not indeed lay any stress on the remarks of Stukely, who calculates from the compass of country over which earthquakes have been felt, that the force must in some instances lie 200 miles beneath the surface, because there seems reason to believe that vibrations may be propagated laterally beyond the immediate influence of the impelling force; but I would argue from the immense mass of materials ejected by any one volcano, as for instance by Etna or Vesuvius, without exhausting itself or causing any sinking of the mountain; from the prodigious height to which the trachytic nucleus of others seems to be raised, as at Teneriffe and in Equinoctial America; and lastly, from the immense violence of the eruptions themselves, which would shiver into pieces any merely superficial covering of rock, that the elastic vapours must be disengaged from a very great depth at least, if not from one equal to that to which the crust of the earth may be supposed to extend.

Having now examined the products of subterranean fire individually, I will next consider them in the aggregate, and explain the manner in which they produce those vast accumulations of volcanic materials which occupy so large a portion of the surface of our globe.

Those observers who have been fortunate enough to obtain a near view of the crater of a burning mountain, in what is called its active condition, inform us that the interior of it is filled with a body of melted lava, which may be seen alternately rising and falling within the abyss.

At its maximum of elevation, one or more immense bubbles have been seen to form on the surface of the lava, and rapidly

swelling, to explode with a loud detonation. This explosion drives upwards a shower of liquid lava, which cooling rapidly in the air, falls in the form of scoriæ. The surface of the lava is in turn depressed, and sinks several feet, but is propelled again upwards in a moment by the rise of fresh volumes of elastic fluids, which escape in a similar manner. Such is the account given by Mr. Scrope of the crater of Stromboli, which he surveyed from a commanding point of rock; such likewise in the main is that given by Spallanzani of Etna, by Bory St. Vincent of the volcanos of the Isle of Bourbon, and by Ellis of Kirauea in Owhyhee. In all these cases a mass of melted matter of unknown depth, covered for the most part with a thin pellicle of scoriform lava, and emitting copious volumes of steam or gas, was perceived in the crater which these observers overlooked.

Now it is evident, that the tendency to eruption in such instances will depend upon the relation existing between the expansive energy of the materials, and the controlling force derived, in part, from the pressure of the superincumbent atmosphere or ocean, and in part from the weight of the column of liquefied matter; and that as in general a considerable proportion of the matters ejected during a paroxysm of volcanic action falls back into the crater, whilst the elastic fluids which served to expel them escape, the active state of a volcano will be intermittent, and its eruptions placed at distant intervals asunder.

In a few rare instances, as at Stromboli, where, from some peculiarity in the configuration of the mountain, the whole of the ejected materials falls into the sea, and is carried away by a strong current to a distance, the repressive and expansive forces may be so equally balanced, that a series of explosions shall occur at short intervals for any length of time during which the volcanic processes continue, without any accession of violence ever taking place, sufficient to produce the emission of a continuous current of lava. In cases where the opposite forces are so nicely balanced, it may happen that the mere variations of atmospheric pressure will cause a difference in the explosive force, and thus may be explained what the inhabitants of that island have from time imme-

morial remarked, that the intensity of the eruptive violence is greatest in stormy weather.

It is evident then, if we suppose this to be the condition of every active volcano, that when once the violence of its operations has arrived to such a pitch as to overcome the resistance opposed to it, the elastic vapours will throw out portions of liquid lava, just as when a mass of melted metal happens to fall into a vessel containing water, the steam generated disperses it in all directions. These portions of lava projected into the air will descend again in the form of scoriæ or sand, and collect into an aggregate, which has been called, rather improperly perhaps, a bed of volcanic tuff.

But the projection of these fragments is soon followed by the overflow of the melted lava itself, which by degrees reaches the brim, spreads over the tuff, and forms a regular bed encircling the original aperture.

Now the repetition of these successive operations might cause that alternation of beds of lava and tuff, which is found to constitute the sides of most volcanic craters, and it will be at once seen, that the direction in which they lie, to appearance horizontal, when viewed from the interior of the chasm, but in reality dipping on all sides away from the centre at an angle of about 30°, is exactly what would happen if we suppose them formed in the manner represented. In the woodcut annexed to page 202, the disposition of the beds in a crater of eruption is given, and, as contrasted with it, is shown that of the beds on a hill, which may chance to have been hollowed out by the action of water, in a manner which causes it to correspond in external appearance with that belonging to a crater, after the latter has been broken away and partially destroyed by the influence of other agents.

It is true that we can hardly imagine many hundred alternations of strata so constituted to mantle round the crater in the way supposed, for it is evident that the slightest irregularity in the brim over which the lava flowed, or upon which the scoriæ descended, would determine these materials more on one side than on the others, so that there would never be found, after the first few beds had been formed, any that actually extended round the whole circumference.

But Mr. Lyell has stated from actual observation, that this appearance of uniformity is delusive, and that the cone is in reality composed of a number of beds, each of which thins out so gradually as to be confounded, and to appear continuous, with some other placed next it.

The above statement of the ordinary succession of phænomena occurring during a volcanic eruption, which we owe originally to M. Necker de Saussure, supplies us with a simple and apparently natural explanation of the structure of an ordinary cone—the quâquâversal dip of its strata—the regular alternation of tuff and lava, and even perhaps of the dykes which intersect them. But are we at liberty to infer, that the whole of a volcanic mountain, whatever may be its form, antiquity or position, whether situated, like Vesuvius, on the borders of the sea, or, like the Peak of Teneriffe, in the midst of a fathomless ocean, is built up entirely after this fashion?

Even in the absence of any direct evidence on the subject, we should be inclined to hesitate before we adopted such a conclusion, and to ask ourselves whether, under so enormous a pressure as that of the ocean, the expansive force of elastic fluids struggling to escape, would not be more likely to upheave in the first place within a given area, the strata nearest to the focus of the action, when softened by the heat, than to eject fragments of rock round a cone in the manner represented.

We might also feel perplexed to explain on such a supposition the appearance of any detached volcanic mountain in deep water, since such materials, if accumulated under the sea, would be too quickly diffused over its bottom to raise the level to any considerable height at one particular point.

It would also seem, that if earthquakes are allowed to have brought about an occasional upheaving of the earth's surface, and that without producing such a confusion of the strata affected, as even to interfere with the springs of the country, or to throw down the buildings erected on the spot, there would be still greater reason for attributing such effects to volcanic action exerted upon rocks which had been actually softened by the previously existing heat.

But independently of these probabilities, there are not wanting direct proofs of the upheaval of rocks that appear to be connected in some way with volcanic operations; proofs derived in certain cases from the appearances they present, and in others from the actual testimony of eye-witnesses.

The former class of proofs may be drawn from the examination of volcanic mountains, whose interior structure is from some cause or other exposed to view in such a manner, as to reveal to us the real nature of the material which composes its nucleus.

Thus, as has been already stated*, in the island of Great Canary, and still more remarkably in that of Palma, a chasm called the Caldera exists, nearly 4000 feet in depth, which afforded to Von Buch an excellent section of the internal structure of the mountain itself. Lowest of all he discovered the primitive rocks, then masses of trachyte, and above various alternations of those volcanic strata which usually occur in craters. The latter, for aught we know, may have been formed by successive ejections of lava and scoriæ; but the trachyte and the granite underneath must have been upheaved; for why else do we find them at a height, which, though 4000 feet perhaps from the summit, is at least 3000 from the base of the mountain, and consequently from the level of the sea, and that sea too unfathomable? Can we resist the belief, that at least the granite with its superincumbent trachyte was upheaved from the bottom of the ocean by volcanic agency, and thus constituted a nucleus, round which the subsequent ejections have taken place?

The aspect of those narrow and precipitous ravines called *Barancos*, which encircle the flanks of the mountain, favours this hypothesis. They are so circumstanced, that we can hardly attribute them to the action of water; but if we suppose a succession of solid and unelastic strata to be suddenly lifted up in the manner of those in the island of Palma, it is evident that not only would a central aperture be formed where the crater now exists, but that the strain would occasion a number of lateral fissures corresponding with those called in the island by that name.

Of the upheaving of trachyte in detached dome-shaped or

* Page 446–447.

conical masses, and that by forces which we can hardly hesitate to regard as volcanic, examples, we conceive, of even a less equivocal kind, may be found in countries accessible to the European traveller.

To what other cause, for example, are we to attribute the occurrence of those five isolated hills of domite, which we meet with near Clermont in Auvergne, the largest of which, the Puy de Dôme, rises nearly 3000 feet above the general level of the *plateau* on which it rests?

On what possible supposition are we to account for the regularity of their form, their perfectly detached position, and their occurring each in the midst of an amphitheatre composed of volcanic rocks of a totally different kind? Shall we imagine them to be the relics of a continuous stratum once spreading over the adjacent country, but since removed by subsequent changes? or shall we suppose them to be masses of a kind of lava, which, from its imperfect fluidity, accumulated round a central point without spreading into the adjacent plain? The former supposition seems irreconcilable with the fact of the total absence of all traces of the rock elsewhere, and with the conical form belonging to some of these masses; the latter is manifestly inconsistent with its chemical constitution, and the idea of its owing its fluidity to intense heat, which we have thought fit on other grounds to adopt *.

In one of these hills, the Puy Chopine, we appear even to be able to trace the very steps by which the process has taken place. We observe here, not merely a rock composed of that variety of trachyte which in the other four hills constitutes the whole mass, but by the side of it, forming the portion fronting the south-west, south-east, and east, a congeries of various primary and volcanic rocks in different states of alteration. I may enumerate, a conglomerate composed of scoriæ and volcanic tuff, basalt, hornblende, slate, syenite, and granite more or less disintegrated, especially where in contact with the trachyte. The whole of the mountain is

* See this question more fully discussed by myself, in a letter to Professor Jameson on the Diluvial Theory, and on the Origin of the Valleys of Auvergne, published in the 'Edinburgh New Philosophical Journal' for April 1831, and likewise touched upon in the third chapter of this work.

surrounded by an amphitheatre of rocks, composed of a congeries of scoriform volcanic products, from the midst of which it appears to have been elevated; so that we seem to have at once presented before our eyes, the material from which the trachyte was elaborated, the several steps in the change effected, and the mode in which, when so prepared, it was made to occupy its present position.

If however we believe Humboldt, the New World must present a much more decisive instance of the kind than the Puys of Auvergne we have just been considering, since, as we have seen, Chimborazo, till lately considered the highest mountain in that hemisphere, is represented by him as composed entirely of one of the species of trachyte, resembling both in form and composition on the great scale, what the Grand Sarcouy in Auvergne is on a smaller one.

Now we may remark, that it is only because these mountains, owing to the shifting of the volcanic fire to another quarter immediately after their elevation, or to some other peculiarity in their physical condition, have given rise to no ejections of lava or scoriæ, that we are enabled to ascertain so decisively their constitution; for had they assumed the character of permanent vents, and consequently been covered by a numerous succession of layers of volcanic materials, we should then have been induced to conclude that they were entirely built up of that which constituted in reality merely their external superficies.

That domes of trachyte have actually been in some cases instrumental in the elevation of numerous beds of lava and tuff, can scarcely, I think, be doubted by those who have seen the crater of Rocca Monfina or of Astroni, which have however been sufficiently dwelt upon in the former part of my work.

Facts like these are more calculated perhaps to make an impression on the generality of readers, than the refined calculations into which M. Elie de Beaumont has entered, in order to prove on mathematical grounds that the table-land of Mont Dor and of the Cantal must have undergone upheaval.

It may not however be amiss here to remind the reader of the structure of those districts, as explained in the third chapter of this Treatise, from which it would appear, that

they are composed of vast sheets of basalt and trachyte spread in a gibbous form over extensive areas of country.

To trace these formations to any series of volcanic craters which may be supposed formerly to have existed in the country, or in other words, to place them under the same category as the modern volcanic products of the neighbouring district, has I believe never been attempted by geologists of any school; and M. Virlet, one of the most distinguished opponents of the elevation-theory in France, who accompanied the scientific expedition sent by the French government to the Morea, is compelled to admit that the eruptions which built up the Mont Dor and the Cantal must have been on a greater scale than any which we at present experience; thus giving up the very point which pleads most strongly in favour of the rival theory, by admitting that causes now in action, operating with only their present intensity, would be inadequate to produce the phænomena.

It is true the adversaries of Von Buch's theory in this country, more consistent in their opposition, endeavour to show that lava-currents of equal extent have been emitted in modern days; and doubtless Iceland, and even Sicily, afford examples which may be fairly brought into competition with many formations of more ancient date.

But Messrs. Elie de Beaumont and Dufrenoy contend, with great appearance of justice, that it is only when the lava has reached a tract of nearly level land, that it spreads itself over so wide a surface as is there represented, and that during its descent down the sides of the volcano it is almost invariably circumscribed within a very limited area.

When therefore we observe a conical hill composed of sheets of lava or trachyte, which can be ascertained to be continuous round the whole or the greater part of its circumference, we must suppose it once to have been horizontal, and to have been brought into its existing position at some subsequent period.

There are also not wanting instances in volcanic districts, where the ordinary rocks of the country have been heaved up round a circumscribed area, evidently by the expansive force of the vapours from beneath, so as to form crater-shaped cavities, resembling in all particulars, except in their com-

ponent parts, those of an ordinary volcano. Mr. Scrope himself has described one of them, called Le Gour de Tazana, of which mention is made in the third chapter of this work. It has the shape of a crater, but is composed almost entirely of granitic rocks, the scoriæ and puzzolana scattered about it alone serving to indicate the volcanic origin of the basin.

In my fourth chapter also are mentioned similar craters as occurring in the Eifel; and perhaps the best example of them is the circular volcanic lake called the Meerfeld, hollowed out of transition slate and red sandstone, without any admixture of volcanic matter, though surrounded by loose fragments of augitic lava. Now if we admit, that in these instances the rocks in question have acquired their actual position from the operation of expansive vapours acting from below, what reason is there for questioning the possibility of the same forces having affected volcanic strata, and having caused them likewise to be upheaved in a similar manner?

But such, it may be said, is not the structure of Etna or of Vesuvius. In these well-known igneous vents we observe no trachytic nucleus, even where we have the best opportunity of prying into the recesses of either mountain, but throughout nothing is to be seen, but that alternation of lava-streams and beds of tuff or scoriæ which is produced at this very time by the operations of these volcanos.

Yet even here, as has been stated, the compactness, the continuity, the prismatic structure, the absence of scoriform and ropy-looking masses superimposed, by which characters, amongst others, the ancient sheets of lava are distinguished from the modern, have compelled the opponents of the theory of sudden elevation to admit, that they were emitted in a position more approaching to the horizontal than that which they at present occupy.

The discussion therefore seems after all to resolve itself, not into the question as to whether volcanic rocks have been upheaved, but whether their elevation has been sudden and paroxysmal, or gradual and by successive efforts.

Now whatever conclusions we may arrive at with respect to those volcanos that have existed in all material points the same as at present from time immemorial, evidence of an apparently decisive character on this question with regard to

others is afforded us by those persons who have either been eye-witnesses of the formation of a volcano on a new site, or have been situated nearest, in point of time or place, to the theatres of such events. Father Goree, in 1707, was eye-witness of the appearance of a new rock between the two islands of Great and Little Cammeni, off Santorino, in the Grecian Archipelago. He states that it gradually increased in size and in height, until it became half a mile in circumference, and rose twenty or thirty feet above the level of the sea, bringing up with it live oysters. After this had happened, a crater appears to have been formed, from which fragments of volcanic matter were ejected, which latter now cover the surface of the island and conceal the underlying rock.

Methana in Argolis, described in my eighteenth chapter, seems another instance in point, as the tradition of the place, confirmed by the appearances it now presents, leads us to suppose that it was suddenly elevated.

Among the Aleutian group, Langsdorf has described a rock near the island of Unalaschka, 3000 feet in height, consisting of trachyte, which made its appearance in 1795, and seems to have been thrown up all at once from the bottom of the ocean. The island that has recently appeared in the Mediterranean between Sicily and the African coast, though the part elevated above the sea was made up of scoriform matters disposed in concentric layers round a central orifice, seems below to have consisted of an upheaved mass of rock. It is certain at least from Captain Smyth's account, that the depth of the water on the site of the island was not less than 100 fathoms when he sounded it in 1814; and it appears from the chart accompanying Dr. Davy's paper, that it varies in the immediate vicinity of the island from one to twelve fathoms, from whence it gradually increases, so that at a distance of from 100 to 200 yards from it, the present soundings range from twenty to sixty-five fathoms.

Now this change of level may no doubt be explained in two ways; either by the gradual accumulation of scoriæ and other volcanic products, or by the more sudden elevation of a portion of the bed of the Mediterranean. With either hypothesis the structure of the crater is equally compatible; for it is natural to suppose that, after a conical mass had been

upheaved, ejections of scoriæ might have taken place round some central point.

But with regard to the mode in which the operations of the volcano began, I am disposed to give the preference to the hypothesis of a sudden upheaving; for to have raised the bed of the sea from 100 to ten or twelve fathoms water, would seem to require a longer continuance of volcanic operations than is noticed as having occurred on this spot, as well as a wider dispersion of the ejected mass over the sea than appears to have been the case. We hear indeed of scoriæ and ashes having been distributed on all sides, even to the coast of Sicily; but we do not find any sensible difference in the level of the sea recorded, excepting within an area of one or two hundred yards round the island, from which central point, therefore, the bottom appears to sink abruptly in every direction.

Nor must we forget the corroborative fact seized upon by the sagacity of Arago, who argues that the existence of a lower temperature in the sea immediately around the volcano, than at a distance from it, implies a portion of the bed of the Mediterranean to have been upheaved in mass.

I might appeal to the facts stated with respect to the Monte Nuovo in page 208–9, as serving to show that this volcano likewise must have been upheaved, but for fear of indulging too much in repetition shall hasten on, and point out that most remarkable case of sudden elevation which was exhibited in the last century amidst the volcanic country of Mexico.

Here then Humboldt has presented us with an instance where, in the centre of a great table-land, and at a period not more distant than the middle of the last century, both the descriptions given by the inhabitants of the country, who were actual eye-witnesses of the event, and the appearances exhibited at the time the spot was visited by this great observer himself, lead to the conclusion, that a large tract of ground from three to four square miles in extent was heaved up in a convex form to the height of 550 feet, and that from the midst of this protuberance arose six conical hills, the least of them 300 feet in height, and the loftiest, Jorullo, elevated 1600 feet above the level of the plain.

Certain English geologists have questioned the soundness

of this explanation, and have suggested, that the convexity of the plain may have been produced by a simultaneous overflow of lava from the six cones, and that these, uniting into one sheet, may have formed a sort of circular pool or lake of lava.

But this solution seems to me clogged with still greater difficulties than the one offered by Humboldt; for although it be true that the viscidity of a lava-current is such, that we ought not to suppose it subjected altogether to the same laws as those which regulate the flowing of a body of water, still it seems probable, that some trifling inequality of surface in the plain over which it has spread, some variation in the quantity of lava given out from the different orifices, would determine the sheet of lava to one point rather than to another, and thus produce a stream flowing in a given direction, instead of a lake of melted matter circumscribed within so definite an area.

It has been said, indeed, that the heaving up of a tract of land of this kind is unprecedented; but so, it may be relied, is the formation of such a convexity by the mere overflow of a stream of lava proceeding from any existing volcano. And it must moreover be recollected, that, according to the very conditions of the theory advocated by those geologists who have objected to Humboldt's views on this point, our historical records would embrace so very small a portion of the time occupied by any of the great physical revolutions of our globe, that there appears the less reason for restricting geological reasoning strictly to the data obtained by actual observation, provided it assume nothing inconsistent with the laws which the latter tend to establish.

It may also be remarked, that the existence of a hollow space beneath a volcano, which may be accounted for, although it does not necessarily follow, from the uplifting of the rocks composing its nucleus, seems the best and most obvious means of explaining the phænomenon stated by Dr. Horsfield to have occurred in Java, where the mountain Papandayang, formerly one of the largest volcanos in the island, is said to have given way, and in part to have fallen in, so that an extent of ground fifteen miles long and six broad was swallowed up in the bowels of the earth, with the destruction of forty villages and of a large proportion of their inhabitants.

Upon the whole then it would seem, upon a candid survey of the facts before us, that the mere observation of that system of operations which is going on at the present day in connexion with the volcanos most familiar to us in this quarter of the globe, carries us after all but a small way towards the explanation of those varied effects of igneous forces which geology unfolds.

We have seen, for instance, that even the older lava-beds of Monte Somma cannot be referred to such a series of phænomena, unless we choose in addition to admit their subsequent elevation, slowly at least, if not suddenly, to have taken place, and that we can still less account in this manner for craters formed like Rocca Monfina, through which a central nucleus of trachyte has been protruded.

The application of such a theory to the formation of new volcanic islands is, as we have seen, attended with many difficulties; and if, regardless of these, we persist in attributing the rise of Graham's Island and others of recent date merely to a sudden outburst of scoriæ and other loose materials, we by so doing sever the connexion between the mode of their production, and that of other volcanic islands of greater antiquity, which, like the Great Canary, are seen to contain within themselves a central nucleus of trachyte evidently upheaved from the ocean.

Lastly, this hypothesis fails altogether to explain those isolated domes of trachyte which are met with in Central France and in equinoctial America, no less than those extended plateaus of the same rock, which constitute the volcanic ranges of Mont Dor and of Cantal.

There seems therefore no good reason to disbelieve that volcanic rocks have been upheaved both on sea and on land by the expansive force of elastic vapours, nor will there be any reluctance to admit that this upheaval may have been sudden, except on the part of those who would contend for a slow and progressive movement, in the case of all other rocks that have been similarly affected.

That class of geologists at least, who do not object to the notion of paroxysmal actions as applicable to other instances, will probably be induced to consider the facts above cited in favour of the sudden elevation of volcanic mountains as suffi-

ciently substantiating a similar mode of action as having been concerned in their production, and it is for the sake of such persons more particularly, that I shall proceed to state more distinctly than I have yet done the views of Von Buch on the subject before us, without however pledging myself to their adoption in all their details.

Von Buch has distinguished the craters of volcanos into two classes; those produced by eruption and by elevation. The former are brought about in the manner already pointed out by Necker de Saussure and others, and are found in all volcanos which have given rise to currents of lava, or have constituted permanent vents of volcanic materials.

The latter are produced owing to the upheaving of the crust of the earth by the agency of elastic vapours round a certain limited area, and may therefore consist either of the older rocks of the country, or of the products that have been accumulated by antecedent volcanic operations. The one may be illustrated by the crater of Meerfeld in the Eifel, and that of the Tour de Gazana in Auvergne; of the latter, the Puy de Dôme and other conical masses of trachyte afford, it is conceived, unexceptionable examples.

Now as the structure of a crater of eruption has been compared by Mr. Lyell to that of an *exogenous* tree, which increases by layers deposited from without; so that of a crater of elevation may, to follow up the same analogy, be perhaps compared to that of an *endogenous* one, where the growth is caused by the protrusion of a mass from within. The question therefore is, in what way are we to determine whether a given crater, or, to speak more generally, a given volcanic formation, be the result of the one or of the other process?

And here we may obtain assistance from the excellent memoir so often referred to by Messrs. Elie de Beaumont and Dufrenoy, who propose the following method of distinguishing between the two.

When the sides of the mountain are covered with bands of lava circumscribed within narrow limits, we may fairly infe that they have been formed by successive ejections; when, on the contrary, the whole circumference of the cone is over-

spread with a continuous sheet of volcanic matter, which is commonly the case where the substance of it is basaltic or compact, we may presume that it has once been nearly horizontal, and has since become upraised. The former may happen most commonly in those volcanos which are subaërial and at present in action, but the latter is the case generally in those which are subaqueous.

Indeed, when we consider the great pressure to which a mass of lava would be subjected if it were poured forth under the bed of a deep sea, it must be expected to spread itself out more regularly and over a wider space, inasmuch as that tendency to an upheaval in a conical form which manifests itself in subaërial lavas would here be repressed by the enormous weight of superincumbent water.

The subject however of submarine volcanos will come under our consideration in a subsequent chapter, and I shall therefore only at present remark, that the difference in those conditions under which lavas were placed, when beneath the pressure of a large body of water, and that of the atmosphere merely, might alone prepare us to expect corresponding variations in their internal texture, as well as in the character and disposition of the masses which they produce in the aggregate.

Hence there is no absurdity in supposing, that the same elastic vapours which vent themselves upon land in frequent but slight explosions of stones and sand, or in periodical emissions of small streams of lava, may under the sea be so confined, that when they at last overpower the resistance of the water above them, they should heave up bodily the rocks round a given area, so as to form a crater of elevation projecting into the air in the manner that Von Buch has suggested.

CHAPTER XXXVIII.

COMPARATIVE ESTIMATE OF THE MECHANICAL AND CHEMICAL THEORIES.

The two theories equally based upon assumptions.—Mechanica theory explains the protrusion of lava—but does not explain the position of volcanos or other circumstances connected with them—such as the steam and gases evolved—the upheaving force, &c.—Theory modified by supposing water to take part in the operations—gases evolved not explained by this addition—hence combustion of some kind must be inferred—that of the metals of the earths and alkalies most readily explains the phænomena. Objections answered—this view explains the long continuance of the action exerted—mean density of the earth shown to be no objection to it.

Having now discussed in succession the different phænomena found to accompany volcanic action in its various phases of intensity, I have, it is presumed, placed my readers in a position to estimate the relative probability of the two modes of explaining its existence, which have been briefly put forward in a preceding chapter of this work.

I repeat, the *relative probability* of the two; for after all, there will be few so far wedded to either, as not to contemplate the possibility of new volcanic phænomena being brought to light, of fresh facts and principles in chemistry becoming recognized, which may give a preference to some third explanation entirely different from either of the foregoing, seeing that one of those conditions laid down by Lord Bacon as requisite to guarantee our belief in a theory, namely that the cause assigned should be ascertained to have a real existence, can be predicated neither of the one nor of the other.

Thus much I believe will be allowed by the warmest supporters of the mechanical theory; or if there be any who maintain, that the existence of internal fluidity is something more than an hypothesis by reason of the external figure of the earth, which implies that there was once a free movement in its now solid contents, those persons may be reminded, that the high temperature which their supposition involves

would necessarily place the elements of bodies in that very condition, in which the chemical theory assumes that some portion of them exists at present;—I mean, would keep them aloof from those chemical combinations which they have now such a tendency to form. So far therefore as *à-priori* reasoning goes, the two hypotheses appear to start upon even grounds, and the question really at issue stated in its broadest terms seems to be simply this—whether the phænomena of volcanos are such as imply a process of oxygenation or not: if they do, then our acquaintance with bodies, which are kindled by the mere contact of water, enables us to explain the manner in which the process may originate, its continuance becoming a question for subsequent consideration; whilst if the phænomena before us can be accounted for merely by assuming the presence in the interior of the globe of a mass of matter in a state of liquidity, we should perhaps be scarcely disposed to look further for a solution of them.

Now the progressive refrigeration of a ball of melted matter proceeding from the circumference towards the centre, might doubtless produce something like an imitation of one volcanic phænomenon, namely the occasional emission of lava-currents, since the contraction of the crust upon its internal contents would squeeze out from time to time, at the points of least resistance, a portion of the liquid proportionate to the gradual diminution taking place in its own capacity.

Elie de Beaumont in France, Dana in America*, Sir H. De la Beche in England, and many other geologists, have appealed to this same contraction of the crust as the cause of the direction and origin of mountain chains, regarding them as corrugations of the surface caused by an irregular action in the force called into being by the secular refrigeration of our globe.

I may refer to Mr. Dana's Essays on this subject as well-worthy of perusal, and will admit, that the intermittent character of volcanic action, its long continuance without becoming exhausted, and even its occurrence on the coasts, these being the lines of least resistance, may receive from this assumed principle a solution more or less plausible.

* Geological Results of the Earth's Contraction, American Journal of Science, vol. iii.

But on the other hand, it does not appear to me to explain why volcanos should break out in the middle of the sea, where the pressure must be greater than it is on continents, intersected as the latter are with caverns and fissures; why it should take place on certain lines of coast only, and not generally wherever there be low land; and why, fed as they would be by an inexhaustible fountain of melted matter, they should ever become extinguished, or, at least, continue dormant for so very extended a period, as to convey to us that impression.

Neither does this hypothesis explain the differences that exist between the products of distinct, though often contiguous volcanos—of Etna for instance and Lipari; of Monte Somma and Vesuvius—since these, if derived from the same internal source of liquefied matter, ought, as it should seem, to be uniform in their composition and structure.

In conceding therefore, that the conditions of this hypothesis permit us to explain this one phænomenon, my readers may perhaps conceive that I have gone further than I was strictly warranted in doing; whilst with regard to others more characteristic and more essential than even the emission of lava, they will be left by it altogether in the dark.

In what manner, for example, will the admission of Cordier's theory enable us to account, either for the evolution of steam and of the various gases which we have seen to be constantly present, or for those consequences of the confinement of such elastic fluids in the interior of the earth, which manifest themselves in the explosions that accompany an eruption, or in the upheaval of rocks and the production of earthquakes which are referred to their operations? Nor can we be considered guilty of any gratuitous assumption in thus attributing them; for although the elevatory effects of volcanic action have been by some ascribed merely to the hydrostatic pressure of a mass of lava, which had been forced up to the summit of the crater, yet it is plain, that to have brought it into such a position in defiance of gravity, some powerfully acting force must have been concerned; and what force at once so probable in itself, and so adequate to the effect brought about, can be suggested, as the evolution of a great body of elastic

vapour, the existence of which moreover we seem compelled from many other considerations to admit*?

Aware perhaps of the difficulties that suggest themselves to Cordier's theory in the simple form in which it has been above enunciated, many who are held to support his views call into play another principle, namely water, which according to them makes its way to depths where the earth is supposed to maintain a temperature sufficiently exalted for their purpose, and is thus converted into steam, which serves by its elastic force to eject the various heated matters that issue from the orifice.

It must be confessed, that such an addition to the theory supplies us with an explanation of much which the former view of it had overlooked, especially the power which volcanos exert in upheaving rocks, and in general the expansive force which constitutes one of the most striking features connected with their manifestations. Yet even here, unless we suppose some kind of combustion to take place, we are left in the dark with regard to the evolution of sulphurous acid and of nitrogen gases; and without assuming the existence of some principle or other capable of decomposing, as well as converting into vapour, the water that finds admission, we shall be at a loss to account for that steady and copious evolution of hydrogen either pure, or in combination with sulphur, which has been already noticed.

It may indeed be said, that sulphurous acid would arise from the spontaneous union of sulphur with oxygen at the high temperature to which it would be subjected, if it existed so deep within the bowels of the earth; and that several of the common metals, especially iron, are capable of decom-

* Cornelius Severus, in his poem on Etna, seems fully sensible that gaseous exhalations are the cause of volcanic phænomena. See the lines beginning—

Non propera est igni par et violentia semper,
Ingenium velox illi, motusque perennis;
Verum opus auxilio est, ut pellat corpora, nullus
Impetus est ipsi; qua spiritus imperat, audit.
Nunc princeps magnusque, sub hoc duce, militat ignis, &c.

posing water and combining with the oxygen of the atmosphere when subjected to the same heat; whence would result an evolution, both of sulphuretted hydrogen, and of the residuary nitrogen derived from the atmospheric air admitted.

But when the naturalist is once brought to allow, that combustion of some kind or other makes a part of the volcanic process, he will necessarily look to the products of the latter, in order to inform himself what the materials may have been which have brought about the phænomena.

Now we have already seen, that the substances ejected from the crater of a volcano usually consist, in the largest proportion of silex, next of alumina, then of oxide of iron, then of lime, and lastly of soda or potass.

That the elements of these bodies must, some of them at least, have absorbed oxygen from the atmosphere, during the process by which their fusion was effected, seems to follow, from the nitrogen disengaged from thermal waters—perhaps also from the ammoniacal salts which proceed from volcanos; and if we are thus brought to admit, that a metal so oxidizable as iron can exist in its metallic state at these depths, what is to hinder us from going one step further, and applying the same supposition to the bases of the earths and alkalies, so as by these means to obtain a readier solution of the energetic character which we should be apt to ascribe to processes capable of producing the effects witnessed?

It has indeed been alleged, that the two principal constituents of lava, namely the bases of silica and of alumina, are not highly inflammable. Silicon, when perfectly pure, resists a white heat without uniting with oxygen, and aluminium may be boiled in water without decomposing it.

But in the first place it is rare to meet with these oxides, unaccompanied with lime or with an alkali: and the bases of the former we must believe from Davy's experiments to be highly inflammable; the latter we know to be so.

Secondly, silicon kindles readily if united with a little hydrogen or with carbonate of soda; and every chemist knows that aluminium burns with brilliancy when heated to redness with oxygen, and that it dissolves with the evolution of hydrogen in very dilute solutions of potass.

There is therefore no difficulty in imagining the combustion

to be kept up by means of the silicon and aluminium, when once it has been commenced by the action of water upon the potassium, sodium, or calcium present.

It has been objected that hydrogen gas is never emitted from the spiracles of any volcano, as ought to happen perpetually and in enormous quantities, if the combustion were kept up by the decomposition of water. But considering the difficulty of approaching the focus of a volcano whilst in a state of vigorous action, the fact cannot perhaps be with any confidence asserted, especially after the observations of Professor Pilla already adverted to.

One thing at least is clear, namely, that inasmuch as hydrogen combined with sulphur is so constant a concomitant of languid volcanic action, it can hardly be absent in some form or other during a more intense condition of activity, and that if the quantity of sulphur accumulated by certain volcanos affords any index of the volume of hydrogen disengaged, the amount of the latter may have borne some proportion to the magnitude of the operations supposed to be connected with its evolution.

Boussingault* calculates that a single mineral spring in New Grenada gives out in twenty-four hours 38,611 kilograms of sulphuretted hydrogen, and 31,654 of muriatic acid, an amount, as it should seem, far greater than can be accounted for by any superficial processes of a secondary kind that might have supervened†.

The chemical theory has this further recommendation, that it accounts for the intense action which appears to be kept up in some cases without intermission for a considerable period, although it must be supposed to be taking place in caverns, or confined spaces deep within the bowels of the earth.

Had the combustion been of such a nature as to give rise only to some gaseous product, such as carbonic acid, the com-

* Ann. de Chemie, May 1837.

† The sulphur annually yielded by the mines of Sicily varies from about 280,000 to 300,000 cwt., and has sometimes reached 400,000 cwt. (Hoffmann, p. 118), from which some idea may be formed of the enormous amount of hydrogen which must have been evolved from the earth to produce the entire deposit.

bustion would soon have been suspended, or at least checked, by the predominance of a principle so destructive to flame, as we find to be the case in coal-mines that have caught fire. Nor would the result have been different, if sulphur, or even phosphorus, had been the sole materials by which the combustion was maintained, for in either case an atmosphere would have been produced, in which the further oxidation of those bodies could not have proceeded. But supposing the substances inflamed to be metals, which form with oxygen a fixed product, and disengage from water an inflammable principle, as in the case assumed, there can be no reason why the combustion should not continue for ages with unabated vigour, as happens in many volcanos.

An objection against this hypothesis has also been sometimes deduced from the mean density of the earth, which is calculated at five times that of water; and hence it has been concluded that bodies so light as potassium and sodium can make no part of its nucleus.

But in the first place it is impossible to pronounce what influence the force of gravity may have had in determining towards the centre a larger proportion of the heavier principles, if there ever were a time, as the advocates of the opposite hypothesis maintain, when the globe was in a state of fusion, for at this temperature, as we have seen, chemical affinity would be overpowered by the antagonist force of heat. For my own part, I am quite unwilling to dogmatize as to what might happen under such novel circumstances, but may observe, that setting aside all considerations of this nature, we are not obliged to imagine a larger proportion of these alkaline bases to be present, than would be implied by the composition of the lava emitted, and probably we shall find not more than four or five per cent. of potass or soda present in the average of volcanic productions.

On the other hand, the specific gravity of the basis of silica, and probably also of that of the other earths which predominate in lava, is sufficiently considerable to warrant the conclusion, that a mass of matter containing these principles in the proportions indicated, and united with as much metallic iron, as we know to exist in the state of an oxide in the generality of lavas, would form an aggregate possessing a specific

gravity only less by one-fourth than that of the compound resulting from the oxidation of the entire mass.

Let us take, for instance, the analysis given by Dr. Kennedy of the lava from Etna, 100 grains of which he states to consist of:—

	gr.			gr.	
Silica	52	sp. gr.	2·65 = in bulk	19·6	of water.
Alumina.........	19	„	4·20 = in bulk	4·5	„
Lime	10	„	3·00 = in bulk	3·3	„
Oxide of Iron...	15	„	5·00 = in bulk	3·0	„
Soda	4	„	2·00 = in bulk	2·0	„
	100			32·4	

We here find that 100 grains of this lava are equal in bulk to 32·4 of water, and consequently that its specific gravity would be no more than 3·08, supposing it divested of water. Now let us contrast this with the specific gravity of the metallic principles which would give rise to a mineral possessing the above chemical composition:—

	gr.						gr.	
Silica	52	contain of	base	26	sp. gr.	2·0 = in bulk	13·00	of water.
Alumina......	19	„	„	10	„	2·0 = in bulk	5·00	„
Lime	10	„	„	7	„	4·0 = in bulk	1·75	„
Oxide of Iron	15	„	„	12	„	7·8 = in bulk	1·53	„
Soda	4	„	„	3	„	1·0 = in bulk	3·00	„
	100			58			24·28	

Now as 58 grains of these bases in the above proportions would be equal in bulk to 24·28 grains of water, their specific gravity would be 2·38. The specific gravity of aluminium appears not to be ascertained, but probably it is not inferior to that of silicon, which sinks in the strongest sulphuric acid, and therefore is more than 1·83.

The theory therefore I have been advocating leaves the question, with respect to the earth's density, just on the same footing as before. Those who are of opinion that the latter may be explained by the mere condensation of rocks of the same kind as those found near the surface in consequence of the superincumbent weight, as certain metals may be rendered heavier by pressure, are entitled to extend this explanation to the case of the alkaline and earthy bases; whilst those who regard the density of the earth as a proof that some heavier matter must exist beneath, are not precluded from such a supposition, as our theory implies merely the existence of

such a quantity of metallic ingredients as would be sufficient with oxygen to produce the materials ejected, leaving the constitution of the remainder just as open to conjecture as it was before.

It is curious indeed, that whilst some argue, that the kind of matter found near the surface is generally of too light a description to account for the density attributed to the earth as a whole; others, as the late distinguished Professor Leslie, have contended, that these substances would have their specific gravity so much increased by the enormous pressure, that void internal spaces must necessarily be supposed.

On this he founded his singular hypothesis, that the centre of the earth is filled only with light, the rarest body known; an idea, the mere mention of which is sufficient to show, how little we can be justified in rejecting an explanation of facts, merely because it appears to militate against the conjectures that may be conjured up with regard to the internal condition of our planet.

Dismissing therefore this objection, and leaving my readers at full liberty to form their own conjectures with respect to the internal state of the globe;—granting even to such as contend for it, that an internal fluid mass might give rise to some of the phænomena of volcanos;—it is conceived nevertheless that if the opposite theory can explain other effects which the above leaves untouched, in addition to those which it elucidates, we are bound by every rule of sound reasoning to concede to it the preference.

I shall proceed then in the next chapter to exhibit to my readers the Chemical Theory of Volcanos in a more definite and tangible form than I have hitherto done, in order to enable them to test its validity, by examining how it applies to the various phænomena which present themselves in succession during the various phases of volcanic action.

CHAPTER XXXIX.

STATEMENT OF THE CHEMICAL THEORY OF VOLCANOS.

Primordial condition of the globe nebular—sinking of temperature down to the point at which the denser bodies became liquid—further sinking to the point at which chemical action commenced—water and muriatic acid first formed—action of these bodies upon the metals forming the crust of the globe—contraction of the crust from cooling—admission of water to the interior of the earth a natural consequence of this contraction—formation of volcanic products arising out of this—muriatic acid—sulphuretted hydrogen and other gases evolved—the whole of the hydrogen not emitted from the crater.—Formation of ammonia—of carbonic acid—disengagement of nitrogen explained.—Heat diffused through the crust in consequence of the chemical actions set up.

Concluding remarks.—Degree of probability attributed to the different points which the Chemical Theory embraces.—Reasons for putting it forward more prominently than its intrinsic probability may seem to justify.

I PLACE but little confidence in those systems of cosmogony which profess to explain the various changes which our planet has undergone, from the first moment at which its materials were launched into space, down to the present advanced stage of its existence.

Such pictures of nature have to me rather the aspect of a philosophical romance, than of a series of sober deductions from ascertained facts; and if advanced with any higher pretensions than as one of many possible modes in which certain natural forces may have operated, lay the theorist open to the charge of presumption, and shake the confidence of his readers in his authority on other points.

Nevertheless it may not be amiss to show, that the chemical view I have taken of volcanic phænomena does not shrink from the test to which the opposite one has been subjected—that like the latter, it may be made the foundation of a theory of the earth, subject to no greater uncertainties than those to which all such theories are from the nature of the case liable—and that volcanic action may not only be represented in

general terms, as a process of internal oxidation, conducted by the agency of air and water upon the constituents of the globe, but may be referred in all its details and consequences to this same agency,—at least without any flagrant violation of the principles which the theory sets out by assuming.

Let us then take up the subject at the point which cosmogonists of the opposite school are agreed in picturing to us as the primordial condition of our planet—that in which its constituents, from the high temperature they possessed, were in a nebular condition, prevented only by the never-failing force of gravity from being dissipated through space.

Under such circumstances, all the elements of matter would remain in a state of chemical indifference, and the law of gaseous diffusion would occasion their intimate intermixture without any union resulting.

Let us next suppose a diminution of temperature in the course of ages to arise, which should bring down the least volatilizable of these bodies to a state at least of liquidity, and there may then be conceived a certain segregation of the elements, such as should cause the heaviest of them to accumulate in a greater degree in proximity to the centre of the mass.

Thus, iron and some of the more ponderous metals might constitute the larger proportion of the internal parts of the earth, the metals of lime and magnesia might occupy a somewhat higher zone, whilst those of the alkalies arranged themselves above; the whole of course enveloped in an atmosphere consisting not only of its present constituents, but also of hydrogen and chlorine, incapable as yet, from the still exalted temperature belonging to them, of entering into combination with the bodies for which they have an affinity.

But let us imagine a further reduction of temperature sufficient to allow these elements to exert their affinities, and it is evident that by the union of hydrogen both with oxygen and with chlorine, a sea would at length be created, strongly impregnated with muriatic acid.

Now this water acting upon the metallic constituents of the superficial coats of the earth, would generate the alkalies and earths, as well as give rise to combinations between the same bases and the chlorine present in the muriatic acid which it held in solution.

Hydrogen would of course be disengaged by both these processes, but no ultimate diminution in the amount of the sea need result, because whatever hydrogen was at first liberated would speedily recombine with oxygen.

Thus we should have a zone of salt water interposed between the atmosphere and the solid matter of the globe, whilst the latter would consist of a crust of alkaline and earthy materials enveloping an unoxidized nucleus.

If we suppose this crust to contain an excess of silica beyond what could combine with the alumina and alkalies present, a material like granite might result from the intermixture of felspar and mica with quartz or uncombined silica.

I have now brought the earth down to that condition in which cosmogonists of a different school suppose it to have subsisted, when through contractions in its cooling crust, inequalities of surface would begin to take place, and the "*waters be divided from the waters*," by the formation of hollows or depressions, into which the seas might subside. This would take place equally according to the view I have formed of the subject, and would give rise to similar consequences.

Thus the contraction would tend to produce cracks, through which the sea-water might find its way down to the internal portions of the globe; chemical actions would thus be renewed, and fresh volumes both of steam and of hydrogen disengaged.

The latter however would no longer be able to find a ready vent upwards, and in consequence would rend and fracture the crust in various directions; or when in the neighbourhood of rocks softened, though not melted, by the internal heat, would swell them out, and form vast hollows or caverns which they would at first distend.

The pressure outwards would prevent any more water from finding its way into the interior, and thus for the time put a stop to the action; but no sooner did the heat diminish, than the gases contained in the caverns must contract in volume and become condensed, thus creating a partial vacuum, which would be supplied by water when the communication was with the sea, and by atmospheric air when it was in connexion with the land.

No supposition would seem more natural, though some

have made it a ground of objection, than this occurrence of a pressure outwards alternating with one in the contrary direction, according as gaseous matter was generated by the volcanic processes, or condensed by the cooling of the cavities that contained it.

I may fortify these conclusions by the authority of Sir Humphry Davy, who, in a memoir "on the Phænomena of Volcanos," published in the Philosophical Transactions for 1828, remarks, that there is every reason to suppose in Vesuvius the existence of a descending current of air; that the subterranean thunder heard at such distances underneath the mountain is almost a demonstration of the existence of cavities below, filled with aëriform matter; and that the same excavations, which in the active state of the volcano throw out during so great a length of time immense volumes of steam, must, there is every reason to believe, in its quiet state become filled with atmospheric air.

Hence perhaps we may explain a phænomenon that has been noticed during the continuance of an eruption, namely that of the air being heard to rush through the various spiracles of the mountain with a loud, and as it is represented, an almost musical sound.

In this manner then a communication would be kept up between the interior of the earth and the atmosphere, and both air and water would gradually find their way to greater and greater depths in proportion as the crust continued more and more to contract.

At length access would be obtained to that lower zone in which the heavier elements, such as calcium, magnesium, iron, manganese, remained unoxidized, and new products would consequently be formed, which becoming melted along with the more superficial granite, would give rise to combinations of silex with lime, magnesia and the other oxides, and in consequence to the substitution of labradorite for orthoclase, and of augite for quartz. Hence volcanic products, such as greenstones, basalts, or trachytes, would take the place of those granitic ones, which had been the first results of the action of oxygen upon the solid constituents of the globe.

The gases given out under such circumstances will be found to tally exactly with those which proceed from volcanos.

When steam is passed over a mixture of common salt with silica or alumina exposed to a high temperature, water is decomposed, its hydrogen going to the chlorine, and its oxygen to the alkaline basis, whilst the alkali produced unites with the earth, and muriatic acid is disengaged.

The same process taking place in the interior of the earth may account for the large volumes of muriatic acid emitted from all volcanos whilst in a state of vigorous action, alkaline silicates being the probable results.

Owing to the copious decomposition of water in the interior of the earth, hydrogen ought to be liberated, but it cannot be expected to make its appearance on the surface in a state of purity, unless it should happen that neither sulphur, nor any other combustible for which it has an affinity, was presented to it.

Yet we have seen it stated that this gas does so appear at Vesuvius; and supposing the quantity of sulphuretted hydrogen disengaged in other instances be too great, as I believe it is, to admit of being referred to the decomposition of sulphates by organic matter, we obtain just as conclusive evidence in favour of our hypothesis from its presence, as though simple hydrogen had been the product.

If indeed it be true, as my own observations at the Solfatara and elsewhere, and the concurrent testimony of the best authorities tend to establish, that the sulphur accumulated in volcanic districts is derived from sulphuretted hydrogen, decomposed into sulphuric acid, sulphur and water, by the catalytic action which Dumas has so ingeniously pointed out, it would indeed be reasoning in a circle to attribute, first such deposits of sulphur as those in Sicily to sulphuretted hydrogen, and again the sulphuretted hydrogen to the decomposition of sulphates by some unknown accumulations of organic matter existing near them; rather than this indeed it would be better at once to resort to the hypothesis of Gimbernat, who finding some *Zoogene* in the vapours he collected from the fumaroles of Vesuvius*, imagined the volcanic action

* It is hardly necessary to observe, that this zoogene is generated after the water has remained for some time in contact with the air. I have several times condensed the vapours from Vesuvius, but never discovered any zoogene in them.

itself to be set up by the presence of organic matter, owing, I presume, to the remains of some Enceladus of ancient fable putrefying and fermenting beneath the fervid mass.

The co-existence of sulphur in this and other instances with extensive beds of sulphates, as well as the copious appearance of free sulphuric acid in certain volcanic districts now active, are in entire accordance with the opinion as to its origin, which I have above expressed.

We must not however imagine that the quantity of hydrogen which reaches the surface is any index of the amount of oxygenation brought about by the agency of water. It may easily happen that the same fluid acts over and over again as a carrier of oxgyen to these bodies, for it is evident that so long as atmospheric air was present, the disengaged hydrogen would unite with oxygen and reproduce water, ready to serve over again in the process of oxygenation.

We know too, that sulphurous acid and sulphuretted hydrogen mutually decompose each other, forming water and depositing sulphur, so that the absence of either of these compounds at the orifice of the volcano does not prove that it has not been generated within, but only that an excess of the other had accompanied its production.

There is another possible use to which the nascent hydrogen may be applied in the interior of the earth, which deserves a moment's notice, as though conjectural, it does not want analogies to support it.

It is well known that ammonia cannot be formed by any artificial process directly from its elements;—not from the affinity between them being in itself feeble, for when combined they constitute a compound of considerable stability; but from the elasticity of the particles of both bodies, which is such as to place them beyond the sphere of their mutual attraction.

How then, it may be asked, do we account for the first generation of ammonia, without which plants could not have obtained those nitrogenized principles which constitute the support of animal existence?

The only solution of this problem that suggests itself to my mind, is the occurrence in the interior of the earth of great

pressure, which, as in the case of oxygen and hydrogen, may determine the combination of nascent hydrogen with the nitrogen of the atmosphere, both being brought into mutual contiguity by the influence of this cause.

It is possible therefore that a part of the hydrogen may go towards the formation of ammonia, which in combination with muriatic acid often finds its way to the surface.

The carbonic acid which at the present time is so freely evolved from volcanos both active and dormant, may with great probability be referred to the action of heat upon the carbonates of lime and magnesia, and is connected perhaps with the process by which these same bodies are made to unite with silex, so as to produce earthy silicates in the interior of the globe.

But whether the carbonic acid was generated from carbon contained as an original ingredient in the primary strata, or whether it existed from the first as a constituent of the atmosphere*, and by its decomposition supplied the carbon now deposited in the bowels of the earth, is a question perhaps as much beyond our powers of solution, as whether the egg preceded the hen, or the hen the egg.

All we can pretend to say is, that every particle of carbon that is met with in the earth may be conjectured to be a product of organic life, and that scarcely any imaginable accumulation of carbonic acid in the atmosphere need have prevented the process of oxygenation from going on, since potassium at a high temperature decomposes carbonic acid gas, and water may be slowly generated even in a mixture containing a large proportion of this gas.

If it existed in the atmosphere at the time when calcium, magnesium, potassium, sodium, &c., were converted into their oxides, it would naturally become fixed by them, contributing to form their respective carbonates, in readiness however at some distant period to resume its gaseous state, as the wants of the future organic creation required it for its food.

Lastly, when the action became slow and languid, when water percolated slowly to the internal cavities in which the

* Of course I allude to that period when the heat had sunk low enough to admit of the two elements becoming combined.

still unoxidized principles remained, a kind of smouldering combustion might be still kept up by the presence of atmospheric air, the result of which would be a disengagement of nitrogen along with the water heated by its access to the source of heat; and it is easy to conceive that a kind of perpetual current might be established, the cold and heavy atmospheric air descending through one set of cracks or fissures, the heated residuary nitrogen ascending by another. At any rate, the constant occurrence of a larger per-centage of nitrogen in the air that rises from thermal springs, than that which exists in the atmosphere, has always appeared to me a most decisive evidence in favour of the continuance of internal oxygenation up to the present time.

In some such way then we may conceive the action of a volcano to commence and to be kept up; and if we suppose the processes in question to have proceeded on a scale commensurate to the effects attributed to them, they would themselves be sufficient, even supposing central heat to be dissipated, or never to have had an existence, for creating throughout that zone of the earth in which they take place, a temperature so high as to influence all the parts above them, and thus to give rise to the phænomenon of the increasing heat of the globe as we descend, within those narrow limits at least to which human observation has extended.

In thus advocating the Chemical Theory of Volcanos, I am not conscious of being actuated by any other motive than the persuasion I have long entertained, from a dispassionate review of the phænomena, that it is capable of giving a better explanation of their occurrence as well as of their sequence than any other that has yet been devised.

The illustrious Chemist who first suggested it might indeed have been suspected of entertaining a sort of paternal affection for an hypothesis founded upon the most brilliant of his own discoveries; but my prepossessions have been all on the other side, from finding the theory abandoned afterwards by its own parent, and at the same time opposed by so many great names amongst philosophers.

Nevertheless when I consider, that Sir Humphry Davy himself, at the very time when he announced his adhesion to the mechanical theory, admitted that the chemical one was com-

petent to explain all the facts connected with volcanos with which he was acquainted*; and when the only valid reason† which Dr. John Davy‡ assigns for his brother's change of opinion is the absence of inflammable gases, which we have now good reason for believing present during the more energetic phases of action, whilst almost every thermal spring connected with a volcanic district proves them to be emitted during the more languid ones; I do not think myself called upon to relinquish my original views, even in deference to so great an authority.

The chemical theory however has since been assailed by an eminent German philosopher, to whom we are indebted for a most comprehensive survey of the laws relating to the distribution of heat through the interior of the globe.

The objections which he first propounded were answered by myself through the medium of the 'Edinburgh Philosophical Journal,' No. 52, and I believe the substance both of the attack and defence will be found embodied in this and the preceding chapter.

Nevertheless, as the Professor alluded to has since returned to the charge, by honouring my remarks with a notice in a subsequent part of the publication alluded to, under the title of "Additional Reasons against the Chemical Theory of Volcanos," I will, even at the risk of incurring the charge of repetition, introduce into the Appendix of this volume the replies that, as it seems to me, may be made severally to the arguments alleged by him in opposition to my views.

Lest however it should be imagined that I attach an undue weight to this mode of representing the phænomena, or wish

* Phil. Trans., "On the Chemical Phænomena of Volcanos."

† I say the only *valid* reason, because I do not think the presence of bases so inflammable as potassium, sodium and calcium in an incandescent mass of lava, can under any circumstances be anticipated; and with regard to iron, it is remarkable that what exists in lava generally is magnetic, or partly in the state of a protoxide, whilst in granite it exists wholly as a peroxide.

May not the partial change from peroxide to protoxide be brought about by the action of the hydrogen disengaged? and does not the presence of protoxide of iron alone render the existence of the alkaline and earthy bases in lava impossible except saturated with oxygen?

‡ Life of Sir H. Davy, vol. ii. p. 100.

to do more than advocate it as the most plausible account of the facts before us that can at present be offered, I will in conclusion extract the remarks on the subject which I made more than ten years ago in my Report on Mineral and Thermal Waters, undertaken at the request of the British Association, and now published in their 'Transactions*':—

"We ought carefully to distinguish between that which appears to be a direct inference from observed facts, and what at most can advance no higher claim than that of being a plausible conjecture.

"The general occurrence of volcanos in the neighbourhood of the sea, and the constant disengagement of aqueous vapour and of sea-salt from their interior, are facts that establish in my mind a conviction that water finds its way to the seat of the igneous operations, almost as complete, as if I were myself an eye-witness of another Phlegethon discharging itself into the bowels of the earth, in every volcanic district, as in the solitary case of Cephalonia.

"Nor is the access of atmospheric air to volcanos more questionable than that of water; so that the appearance of hydrogen united with sulphur, and of nitrogen, either alone or combined with hydrogen, at the mouth of the volcano, seems a direct proof that oxygen has been abstracted by some process or other from both.

"Having satisfied our minds with regard to the fact of internal oxidation, we naturally turn to consider, what principles can have existed in the interior of the earth capable of abstracting oxygen from water as well as from air, and this leads us to speculate on the bases of the earths and alkalies as having been instrumental in causing it. But in ascribing the phænomena to the oxidation of these bodies, we ought not to lose sight of the Baconian maxim, that in every well-established theory, the cause assigned should be not only competent to explain the phænomena, but also known to have a real existence, which latter circumstance cannot of course be affirmed of the alkaline and earthy metalloids as having a place in the interior of the earth."

But it may perhaps be asked, why waste time in balancing

* Vol. v. for 1837.

claims, which by our own admission are of so uncertain a tenure, that they may, for aught we know, both be superseded by some third hypothesis essentially distinct from either?

To this it may be replied, that the advantage which the chemical theory has over the mechanical one, seems to me to consist in the inducement it holds out for a more minute study of the phænomena themselves. As the mechanical theory confessedly offers no explanation of the manner in which the several products of the igneous action, whether solid, liquid, or aëriform, are produced, but is content to set down the gases at least as secondary, unimportant, and incidental effects, it leads to a neglect of these accessories, and renders the examination of the processes themselves a matter of minor interest.

The geologist who sets out with believing that a volcano is merely due to the contraction of the crust of the earth upon its fluid nucleus, may carry on his speculations a thousand miles from the site of any active vent, just as well as he could do at its very foot.

On the other hand, such knowledge as we possess of the gases that are evolved, is mainly owing to the desire which men of science have felt to compare the products of volcanic action with the conditions of some chemical theory or other.

Thus Gay-Lussac, who first elucidated the subject with the lights of modern science, was also the first to scrutinise the gases evolved, in order to determine their correspondence with the chemical views he entertained; thus Pilla, by a wish to satisfy himself on the important chemical question, whether inflammable gases were emitted during an eruption, was induced to brave the dangers of a near approach to the crater during its most active condition.

Abich too, who explored Vesuvius with the eye of a chemist, has given us some of the most important information we possess with respect to the nature and relations of lavas; and in my own various visits to the volcanos of Italy, it was the wish to verify or correct my preconceived chemical views which chiefly kept alive my interest in the operations I witnessed.

I trust therefore that chemical views with regard to volcanic action will find favour at least until all the various

phases which this Force is susceptible of have been fully observed and duly commented upon; and provided this be the case, I shall care little whether the views of Davy, of which I have stood forward as the humble champion, become ultimately substantiated, or whether they be superseded by some other hypothesis, which equally takes into account the chemical products, no less than the mechanical effects, resulting from this mysterious Cause.

CHAPTER XL.

ON THE ROCKS ATTRIBUTED TO VOLCANIC AGENCY TAKING PLACE UNDER CIRCUMSTANCES DIFFERENT FROM THOSE BEFORE CONSIDERED.

Trap rocks—their general characters—their structure—prismatic—spheroidal—tabular—dykes.—Wernerian theory with regard to trap.—Arguments in favour of the aqueous origin of basalt—shown to be fallacious.—Differences between lavas and basalts explained.—Effects of heat modified by pressure.—Why submarine lavas cool slowly—causes that give rise to vitreous products—lamination of igneous products accounted for.—Process of devitrification accounted for by slow cooling—still slower cooling may produce basalt and other traps.—Why submarine lavas have cooled slowly.—Prismatic structure of trap accounted for, and greater frequency of dykes.—Trap rocks, at what periods formed.—Three classes of volcanic products—their characters stated.—Distinctions between plutonic and volcanic rocks.

HAVING now concluded my intended sketch of the phænomena of existing volcanos, and attempted to explain the causes from which they originate, I shall consider in the next place, the influence which forces of the same description may have exerted in former times on the condition of our planet, the rocks that have been produced by their operations, or which have been altered in character and position by their agency.

It is this part of the inquiry, which connects the subject of volcanos with the other investigations of geology, and renders their study of interest, not merely to the chemist and the natural philosopher, but likewise to all who would attempt to explain the condition, past or present, of the globe we inhabit. I shall therefore proceed to notice the rocks, which, though differing in some respects from those produced by volcanos at the present day, appear, nevertheless, to be derived from the same cause acting under somewhat altered circumstances.

There are few parts of the world that do not offer examples of those Formations, which are comprehended by geologists

under the name of Trap, including, as it does, in its most extensive signification, on the one hand basalts, greenstones, syenites, and wacke, and on the other porphyries, with base of felspar or claystone. To each of these general subdivisions are annexed sundry mechanical aggregates, in which pebbles or angular fragments of the rocks above-mentioned constitute the prevailing ingredients.

The above rocks have this peculiarity belonging to them, that they occur in connexion with all the formations which compose the crust of the globe, from the oldest to the most modern, resting on them in irregular tabular masses, occasionally alternating with, and still more commonly intersecting them at various angles.

When circumstanced in either of the two former ways with reference to the accompanying strata, they have been denominated *beds*, with what propriety will afterwards appear; when disposed in the latter way they are called *trap-veins* or *whin-dykes*; *whin* being a provincial term, originally employed by the colliers in Northumberland to designate any hard stone, but now introduced into the general language of geology, for the purpose of indicating a rock, consisting of basalt, greenstone, or wacke, traversing the strata in the manner that has been represented.

I will consider, in the first place, the general structure of trap rocks, and afterwards those circumstances which may be regarded as peculiar, either to the one or other of the forms in which it is found.

Trap rocks, in some one of their different conditions, present examples probably of every kind of structure which has elsewhere been observed: examined on the small scale, we remark them amygdaloidal, porphyritic and granular; examined on the large, we find them in some instances slaty or fissile, as clinkstone; in others divided into thick tabular masses, as basalt and greenstone frequently are.

But that which peculiarly distinguishes rocks of the Trap family, is the tendency to split into prismatic, or, speaking more generally, polyhedral masses, which structure, though it exists likewise in granitic and a few other species of rocks, is nowhere so frequent, or so well displayed as in these.

The columns vary in the number of their sides from three

to six, seven, and even twelve; they are more generally straight, but not unfrequently curved; in size they may be said to range from an inch to nine feet in breadth, and from a foot to 300 or more in height. They are sometimes continuous for a considerable space; but at other times are obliquely and irregularly divided by fissures or joints, the convex surface of one being inserted into a corresponding concavity of the next.

The columns are usually at right angles to the direction of the bed, but not always so; occasionally indeed they radiate from a central point, forming clusters without any determinate direction, and still more commonly they are placed so irregularly as to interfere one with the other. Sometimes in the same bed, one portion will be prismatic and the rest amorphous; whilst every intermediate condition, from that of jointed columns possessing an almost architectural regularity, to a total absence of all arrangement, will be perceived.

It has been usual to refer this kind of structure to the contraction which the mass underwent during its cooling down from a melted state; and there is no doubt that a prismatic structure may arise from a cause of this kind, as we see exemplified in many modern lavas*, and in the shrinking of masses of clay, starch, &c. But there is one circumstance which seems to prove that the prismatic form of trap is owing to a different cause; namely, that in many cases the columns approximate so nearly, that not even the blade of a knife can be thrust in between them. Now in every instance in which the same kind of structure is produced by contraction, theory suggests, and experience confirms, the conclusion, that a certain interval would be left between the columnar masses so produced.

We must therefore look to some other cause for the columnar arrangement of trap, and probably the true solution will be suggested to us, after considering another kind of structure noticed as existing in these rocks, namely the spheroidal or globular. In this case the rock is either wholly or in part arranged in balls of various magnitudes. The globular form

* Contrast, for instance, the structure of the lava of Niedermennig mentioned in my fourth chapter with that of the columns of the Giant's Causeway.

is very conspicuous in the rock of the Shiant Islands; but according to Dr. Macculloch does not appear to be common. A tendency however to this structure is betrayed in most trap rocks by the manner in which they disintegrate, those even which are columnar exfoliating into spheroidal forms when exposed to the weather. Now it is evident that a series of globular concretions of trap, placed in close contact, whilst in a pasty condition, or in the state of transition from fusion to solidity, would be by mutual pressure converted into a succession of jointed columns, which, owing to slight differences in the compactness and consequent softness of the several parts of the mass, would rarely be exact in their sizes and in the number of their sides, but would exhibit all those variations which, in that respect, columnar basalt commonly displays*. Neither does it follow that they may not in some cases have shrunk, after the prismatic form has been communicated to them by mutual compression, since the latter force would begin to operate from the moment they ceased to be liquid; whereas the tendency to contract would continue up to the time at which the rock had sunk to the temperature of the bodies surrounding it.

I conceive therefore that the spheroidal structure will be found to be the one most prevalent in rocks of the trap family, and that the prismatic is in general only a consequence of it; the former indeed arising from that species of molecular attraction, which begins to display itself in all melted bodies from the moment they cease to be absolutely fluid up to the time at which they become completely solid. Hence the longer the interval between these two points, the more fully does this disposition operate, as has been shown by Mr. Gregory Watt† and others, who caused the particles of glass, and even of lava, to arrange themselves in spheroidal concretions, by allowing them, after being melted, to return to a state of solidity with sufficient slowness.

Having now considered the general structure of trap rocks,

* This and the other facts which bear out my hypotheses are beautifully illustrated in the case of the Kase-Keller near Bertrich, described in my 79th page.

† Phil. Trans. 1804.

I will next examine the peculiarities belonging to either of the two conditions in which they exist.

One of the most common forms in which the harder varieties of trap are found, is in large overlying masses, sometimes rising into high mountains, but more generally capping the summits of hills of comparatively low elevation. These latter sometimes would seem to indicate stratification; but the appearance they present is owing to their division into large flat tables, which again have a tendency to decompose, in an abrupt manner, at right angles to the seams of the stratification, thus exhibiting a series of mural precipices, ranging one above the other, from which the term *trap*, which in Swedish signifies a *stair*, has been applied to them.

In other cases they appear to alternate with the rocks of the country, but this appearance is most frequently, though not always, deceptive. Dr. Macculloch has shown that many veins of trap put on a form so far parallel to the stratification, as, when partially viewed, to possess the semblance of beds *. Their true nature may in these cases be determined by finding that the parallelism is not long maintained, but that any one such supposed stratum quits its place to intersect the adjoining and including stratified rock, or sends ramifications through the whole series.

In a few cases, where deep sections of cliffs afford opportunities for examination, it is found that irregular masses lie beneath the stratified rocks in some places, just as they surmount them in others; and that, from these also, veins proceed to the surface, or in other directions.

Without therefore denying that alternations of trap rocks with neptunian deposits may occur,—a consequence indeed which would necessarily ensue, if successive formations of the former rock had taken place at the bottom of water, whilst the latter was in the act of throwing down deposits of clay, limestone, or sand,—let us go on to consider the case of veins or dykes, to which class the great majority probably of stratiform masses of trap actually belong.

These dykes occur of all sizes, from a few inches to twenty or thirty yards in thickness. They extend in some cases many miles in length, as in the case of the great Cleaveland

* See page 250.

dyke, in the North of England, which has been traced in a direct line more than seventy miles. They seldom ramify, but pursue their primary direction in one continuous line. They are usually intersected by fissures at right angles to their walls, and are thus divided into irregularly prismatic concretions.

They often penetrate rocks belonging to different epochs, and wherever the circumstances of the country allow us to follow them for any distance, have been found connected with some great mass of the same material. From their superior hardness and durability, they generally resist decomposition better than the rocks which they intersect, and consequently stand out above the surface of the ground like walls of stone, whence indeed they are termed *dykes*, the terms *wall* and *dyke* being synonymous in North Britain.

Their effects upon the contiguous rocks are very remarkable. The latter are often thrown down on one side and elevated on the other, as if by the forcible intrusion of the trap. The same thing occurs when two trap dykes cross one another, that which has been shifted being considered as of the greatest antiquity. The adjacent rock is variously altered according to its mineral constitution. If it be limestone, it often becomes compact and crystalline, like marble; if shale or slate-clay, it is turned into a substance resembling flinty slate or porcelain jasper; if sandstone, it is rendered hard, and in a few cases prismatic; if it be gneiss, it is converted into a kind of hornstone (Nigg, near Aberdeen).

But the most striking alteration is observed where the dyke intersects the carboniferous strata. In some cases (Cleaveland) the substance of the coal in immediate contact with the trap is changed into soot, whilst at a little distance it is reduced to a coke or cinder, wholly destitute of bitumen. The roof of the mine just above the coal is lined with crystals of sulphur, which may have been sublimed from the bed itself.

Nevertheless these effects do not appear to be universal, and it sometimes happens that a dyke will traverse a series of rocks for a vast distance, without in the least affecting them. These changes are also much more commonly produced by dykes than by overlying masses of trap, though the case of

the Meisner shows that a similar influence is sometimes exerted even by a bed of greenstone overlying coal.

Such then are the principal facts that seem agreed upon with respect to the composition, structure, and position of trap rocks; and the conclusion to which the greater part of them evidently point is, that they have been produced by igneous action of a kind similar to that by which volcanic products are forming at the present day.

Their chemical constitution can hardly be held consistent with any other supposition, for they have been found by Kennedy to agree very nearly in this respect with those volcanic products which they most resemble mineralogically, consisting, like the latter, of compounds of silica, with alumina, lime, and an alkali; substances which have never been known to enter into chemical union except under the influence of a high temperature, and have not yet been found as parts of any neptunian deposit, except as rolled masses derived from another quarter.

The general correspondence in mineralogical character, which may be traced betwixt trap and volcanic rocks, is still more conclusive. Thus the basalts of the one find their analogues amongst the augitic lavas of the other; the syenites and greenstones correspond with the greystones or tephrines, which include the generality of modern lavas; and the claystones and felspar porphyries with the trachytes that so often form the nucleus of a volcanic mountain. We even discover occasionally, in the midst of the products of volcanos that have been in action since the valleys of the country were excavated, and therefore at a recent period, rocks so nearly identical in characters to those which usually are considered as trap, that we cannot deny that the latter do in fact result from volcanic processes. Of this kind are the basaltic colonnades which occupy the bottom of the valleys in the Vivarais, and have evidently been derived from the volcanic craters above them. The mineralogical and chemical composition, as well as the prismatic structure of these basalts, are precisely the same as of those met with in trap districts, the only distinction that can be perceived being the presence of void cells or cavi-

ties of very minute size, for the latter seldom exist in older traps without being occupied more or less with crystalline matter.

Neither would it be difficult to find among the trachytes of Hungary, Auvergne, or the Euganean Hills, rocks identical in structure and composition with the porphyries of older date, as for example are those which accompany trap rocks at Sandy Brae in the county of Antrim.

The inferences too, which an examination of rocks, placed as it were at the opposite extremities of the series in point of antiquity, could not fail to suggest, are greatly confirmed by observing the appearances presented by those which belong to an intermediate age. From whatever cause it may have arisen, it is at least certain, that connected with the deposits belonging to the tertiary period is found a class of rocks, which, if regarded as volcanic, seem often to present the characters of trap, and if considered as trap, to put on frequently the characters of recent volcanic products. Such are the formations of the Val di Noto in Sicily, those in several parts of Italy, in Auvergne, in Hungary, and in other parts of Europe, all of which have been traced to a particular period in the history of our planet; namely the one subsequent to that at which the chalk appears to have been deposited, but antecedent to that in which the earth was peopled by its present races of mammalia.

Nothing, it is clear, could afford a more striking proof of an identity in the origin of trap and volcanic rocks than this apparent transition from one to the other, in proportion as the circumstances under which they were formed came more and more to resemble those of the present time.

Yet, notwithstanding this accumulation of evidence in favour of the community of their origin, it is no long time since the opposite opinion was espoused by some of the most distinguished geologists in Europe; and a theory, at once clumsy and gratuitous, was invented, for the purpose of explaining, without having recourse to igneous agency, the position which trap rocks occupy, incumbent on whatever stratum might chance to be uppermost.

No doubt the weight attached to the name of Werner, who was regarded not unjustly as the Father of scientific

geology, gave to his views on this subject a currency which they would not otherwise have obtained; but even such an authority would not have induced his disciples so generally to adopt his opinion, had there not been difficulties in the way of the opposite doctrine, which served in some degree as a set-off to the glaring absurdities of their own. We ought indeed, in candour, to suppose that the Neptunians, as they were called, agreed only in rejecting the volcanic theory of trap as supported by insufficient evidence, and that the majority of them entertained no very decided views with regard to the manner in which it was really formed. Werner indeed had called up the ocean to the very summits of the hills, at a period subsequent to the deposition of the other rocks, in order to overspread the earth with the materials of his *newest flœtz trap formation*; but his followers must have regarded this idea merely in the light of a suggestion thrown out in order to show, that other possible modes of accounting for the origin of trap might be imagined, without invoking the aid of the God of Fire.

I shall not therefore concern myself with this hypothesis, to which few probably ever attached implicit confidence, but will merely consider what was the nature of those difficulties that induced so respectable a class of geologists, with Werner at their head, not very long ago, to withhold their assent from the position that trap rocks were the volcanic products of an earlier period.

For this hesitation Werner, I am aware, has been severely censured by geologists of the present day; but I apprehend that he is to be blamed, not for having withheld his assent to the propositions of the Vulcanists when he first promulgated his views, but for having at a later period neglected to hold out to his pupils the question as one which required further investigation, and that the opinions which he had taken up in early life would in no degree have lowered his reputation, had they not been adhered to with so much pertinacity to the end of his career, in spite of evidence subsequently brought together*.

* Some allowance nevertheless ought to be made for Werner, when we consider the advanced period of life to which he had attained, before the evidence in favour of the igneous origin of trap rocks had arrived at that

To me however, aided by the lights afforded by more recent investigations, it will be an easy, though not an uninstructive task, to furnish a solution of these supposed difficulties, in doing which however I shall confine myself to one only of the rocks referred to—I mean Basalt, conceiving the whole question as to the formation of other members of the series to hinge entirely upon the result of our inquiry with respect to this.

The aqueous origin of basalt was asserted, or rather, to

degree of conclusiveness which would have justified a decided opinion on the subject. It was his misfortune indeed in some measure to have outlived his system, and to have remained stationary at the very time when Geology was making its greatest progress; whence it has happened, that his services have been as much depreciated latterly as they had been overrated before.

In order therefore to form a fair and candid estimate of his scientific merits, we ought to view him at the commencement of his career, or at least carry our ideas as far back as the period at which his school was resorted to by individuals of almost every nation, as the only then existing source of sound and practical information on the subjects which he taught.

Geology indeed, as it was studied at Freyburg, bore at that time about the same relation to its condition elsewhere, as history does to mythology, or chemistry to alchemy; and if it be objected that even Werner did not altogether emancipate himself from the fables and chimæras that occupied his brethren elsewhere, it may be answered, that his defenders, at least at the present day, neither claim for him infallibility, nor an exemption from human infirmities.

To say therefore that Werner's geological system partook at first of the imperfections belonging to a new branch of knowledge, and that in his advanced years he felt reluctant to modify it, as a younger man might have done, in proportion to the new light that the science had received, is a reproach indeed, but one which applies too generally to bear very heavily on his individual reputation.

Without then professing that blind admiration for Werner, which his pupils at one time appear to have entertained, I cannot help considering, that the branch of natural history which he cultivated is greatly indebted to his exertions; and though the time, it must be confessed, is gone by, in which an exclusive addiction to the tenets of this or any other school of geology can be defended, yet I am on the whole inclined to think, that even the exaggerated opinion entertained with respect to the merits of the Wernerian system may have had its use, as tending more fully to inculcate those principles of classification, and that method of discriminating rocks and minerals, which, with all their imperfections, must be allowed to possess no slight superiority over preceding ones, and to have facilitated upon the whole the advances that have been since made in this department of knowledge.

speak more correctly, its igneous origin was denied, partly from its relations to other rocks, and partly from its own composition, structure and position.

It was shown to pass, on the one hand into greenstone, and on the other into wacke, both which substances, it was argued, must have been formed by water;—greenstone, because, if it had undergone fusion, the crystals found in it would have been obliterated; wacke, on account of its passage into clay, and similar confessedly neptunian deposits.

It was also found to alternate repeatedly with these latter, often without effecting any apparent change in their nature.

The composition of basalt, it was said, contradicts the idea of its having been affected by fire;—it contains water, which does not exist, as had been shown by Kennedy, in the recent lavas most nearly allied to it;—it contains various crystals, which are fusible at a heat below that at which basalt melts;—and it even envelopes masses of limestone, containing all their carbonic acid, and occasionally with their petrifactions uninjured. The structure of basalt is, it was alleged, still more strongly opposed to such an opinion: instead of being vascular, harsh, and vitreous, like modern lavas, it was compact, stony, and sonorous, like iron; instead of being split into irregular, polyhedral masses, with wide, intervening spaces, it was often divided into prisms affecting a great degree of regularity, and closely touching each other.

Unlike lavas, it cannot be traced to a crater; nor does it, like them, descend into the bottoms of valleys, but is found often capping hills, at the very time when it is entirely absent from the low country contiguous.

As to the similarity between basalt and lava in point of chemical composition, it was argued, that this only proved the latter to have been derived from the fusion of trap, not the former to have been produced by heat itself.

Some of these arguments, no doubt, were founded on a mistaken representation of facts: thus wacke being an earthy kind of trap, and containing the same ingredients as basalt, may be produced in some instances from the disintegration of the latter rock; and when that is the case, its further decomposition would give rise to a rock nowise different from clay. All the cases, probably, in which the passage from basalt to clay has been asserted, fall under this predicament.

The greater number too of the instances cited, in which organic remains are said to have been detected in trap, are equally erroneous; the rock in which they are found being a trap tuff, as in the island of Canna; a wacke, derived probably from the decomposition of basalt, as at Joachimstahl in Saxony; or, lastly, a rock altered by the contact of basalt, as the flinty slate of Portrush near the Giant's Causeway, which contains ammonites.

But even if basalt had in any instance been found to contain organic remains, this circumstance would be no more than what has been met with among the ejections of volcanos. Thus, as Sir Henry De la Beche informs us, in Signor Monticelli's collection of Vesuvian products at Naples, occur fragments of the compact limestones of the district with their organic remains imbedded; and we have already seen, from the existence of infusoria in volcanic products, that nothing short of actual fusion can obliterate the traces of organization from a rock that has once contained them.

The presence of crystals fusible at a heat below the melting-point of their matrix offers no objection to the igneous origin of trap, now that it is conceded that these very crystals may have been produced subsequently, owing to the play of affinities brought about by the fusion of the mass, and continuing to operate during the whole period of its return to a state of solidity.

But there are other manifest differences between basalts and lavas which require to be accounted for before we allow ourselves to refer the former to volcanic agency; namely their greater compactness and more stony aspect, the general absence of glassy and of vesicular products, the more regular prismatic structure which they assume, their originating in dykes and not in craters, and other peculiarities above alluded to.

It remains then to be seen, what were the conditions which caused the volcanic products of an earlier period to assume an appearance, in many respects so different from that which they affect at present.

One circumstance will immediately occur to us, as establishing a distinction between the two cases.

We have seen in the former part of this chapter, that up to the period of the tertiary formations the greater part of the globe, or at least of that portion of it which has come under our observation, was covered to a great depth by water; for although the formation of beds of coal, the occasional occurrence of freshwater shells, and that of the remains of land animals, convince us that certain portions of what is now dry land was even at that time elevated above the seas, still it is probable that these constituted merely detached islands in the midst of the abyss of ocean, and that the great bulk of our continents were at that period submerged. It follows from this, that the majority of the trap rocks then formed must have constituted submarine lavas, and hence we see at once a distinction between the above and those of the present day, which, wherever they are presented to our observation, are necessarily subaërial, or at least consolidated only in shallow water. Thus in the volcanic island recently produced in the Mediterranean, the products that have come under our notice are porous and vitreous, like those of Vesuvius; but these, though resulting from a submarine volcano, have all been ejected into the open air, and consequently partake of the character of subaërial lavas.

This distinction, first pointed out by Dolomieu and Strange, was happily applied by Dr. Hutton, in his celebrated 'Theory of the Earth,' to account for the differences between trap rocks and lavas, on the principle that the effect of the heat applied would be modified in these two cases, by the influence of the pressure exercised by a superincumbent ocean upon the former, and by the absence of any such pressure on the latter.

"The tendency of an increased pressure," to use the words of his illustrator, Professor Playfair, "on the bodies to which heat was applied, is to restrain the volatility of those parts which otherwise would make their escape, and to force them to endure a more intense action of heat. At a certain depth under the sea, therefore, the power of a very intense heat might be unable to drive off the oily or bituminous parts from the inflammable matter there deposited; so that, when the heat was withdrawn, these principles might be found still united to the earthy and carbonic parts, forming a substance

very unlike the residuum obtained after combustion under a pressure no greater than that of the atmosphere. It is in like manner reasonable to believe, that on the application of heat to calcareous bodies under great compression, the carbonic acid would be forced to remain, the generation of quicklime would be prevented, and the whole might be softened, or even completely melted, which last effect, *though not deducible from any experiment yet made*, is rendered very possible from the analogy of certain phænomena."

These latter anticipations were soon after realized by the masterly experiments undertaken by Sir James Hall, which showed that the carbonic acid usually driven off from limestone by the action of heat may be retained in combination with it under a pressure greatly inferior to that of the present ocean; and that the calcareous matter under such circumstances enters into fusion at a temperature which it completely resists when this elastic material is expelled.

It is true we have since found, that in a perfectly dry and still atmosphere limestone retains its carbonic acid at a high temperature, even at ordinary pressures; but such a condition of things can hardly take place in nature; and hence the difference pointed out by Hutton between submarine and subaërial lavas, although it may be explained rather differently, must still be admitted as a fact.

Sir James Hall has applied this theory with great success to account for the calcareous matter occurring in the cavities of amygdaloidal traps, and of the water present in those of certain agates existing in the same class of rocks. To the same cause may also be referred the greater cellularity which modern lavas possess than the generality of traps; the former, even in the innermost part of the stream, where, owing to the pressure of the superincumbent mass, their density will be greatest, exhibiting a number of minute vesicles, the existence of which serves to distinguish them from ordinary basalt.

Not that we must suppose all trap rocks to be destitute of cells, any more than we are warranted in inferring, that all the eruptions that took place at these periods necessarily occurred in deep water.

The existence of amygdaloids, such as are the toadstones of Derbyshire, seems to imply, that the pressure under which

certain traps were formed was not sufficient to prevent the disengagement of aëriform fluids; for it is difficult to reconcile this phænomenon with the theory of Sir James Hall, who imagined that such cavities were caused by the infiltration of the crystalline matter, which, when it entered into fusion with the whinstone, kept separate from it, as oil does from water. If this had been the cause of the cavities, they ought to be entirely filled with crystalline matter, which is not the case. Neither is the presence of crystalline matter occupying the cavities a fact absolutely without exceptions. Dr. Macculloch instances the trap of Little Cumbray, in the Kyles of Bute, as consisting of vesicular lava, so light as almost to float on water, having its cells entirely empty, and with a glazed internal surface, like that of volcanic scoriæ.

But these partial exceptions will not be considered as sufficient to invalidate the general position, that traps are of submarine origin, until some geologist will either undertake to explain, on some other principle, the differences allowed to subsist between them and lavas, or will point out the inadequacy of Sir James Hall's theory to account for these points of distinction.

It is true, that the stony aspect belonging to basalt, and the crystalline or granular appearance distinguishing greenstone and other members of the trap formation, characters not applicable to modern lavas, all of which are more or less vitreous in their fracture, and more homogeneous in their general aspect, flow less obviously as consequences from the principle therein assumed. In order however to obtain a clear understanding of the cause of these differences, it will be requisite, first, to show that they are connected with the rate of cooling which the melted mass has undergone, and secondly, that this rate would be slower under a deep sea, than either in shallow water or in the open air.

In the second chapter of this work it was laid down, that the vitreous character of a mass which had undergone fusion was in a certain degree dependent on its composition, for that compounds of three atoms of silica with alumina were alone capable of entering into that condition, or of assuming the form of obsidian. But something more than a peculiar che-

mical constitution is required for the formation of this mineral, for just as glass when very slowly cooled is converted into an opake earthy-looking mass, in which a certain degree of segregation of parts is perceptible, so obsidian may by the same means be converted into a substance resembling trap, as Mr. Gregory Watt and others have demonstrated.

On the other hand, although lavas of ordinary composition, or containing less silica, and more lime, magnesia, and iron than trachyte, will scarcely under any circumstances be converted into a perfect glass, yet a certain approach to the vitreous character is in all cases distinguishable throughout the mass, except in its interior, where it has been subjected to pressure of a considerable weight of superincumbent matter.

It may also be remarked, that obsidian always appears to contain about ten per cent. of alkali; but this, although a necessary condition for its assuming a vitreous character, is not alone sufficient to produce it, for many lavas which are very imperfectly vitreous, possess as much.

Its presence however may assist in explaining the formation of pumice out of the materials of obsidian, for pumice seems, from the analysis of Abich, to contain more soda, but less potass, than obsidian, although the aggregate amount of the two alkalies, taken together, nearly corresponds. This chemist therefore imagines, with much ingenuity, that pumice may be formed by the disengagement of a part of the potass present in the obsidian, as well as of the chlorine of the sea-salt which has come into contact with it whilst in a state of fusion, the soda resulting from the sodium set at liberty at the same time taking the place of the potass evolved, and combining with the mineral mass. We thus arrive at an explanation at once of the porous texture of pumice, and of the larger amount of soda which it commonly contains. A substance resembling pumice may indeed be formed by the mere exposure of obsidian to an intense heat, but in this case there is a loss of potass, without any substitution of soda.

So far therefore as regards the vitreous structure of obsidian in its simple form, the above remarks may perhaps supply us with a sufficiently simple explanation of the facts before us; but there are many varieties of texture, and grades of transition

into other igneous products, that deserve a separate consideration.

Thus for instance I have already* pointed out those little spherical opake concretions, called sphærulites, which are generally referred to an incipient crystallization of the mass arising from a slower cooling, but Mr. Darwin, in his account of the island of Ascension†, has described several other varieties of form and structure :—

1st. A pale grey, irregularly and coarsely laminated, harsh-feeling rock, resembling clay-slate which has been in contact with a trap dyke, and with a fracture of about the same degree of crystalline structure. It is generally honeycombed with irregular, angular cavities, and is in some cases marked with thin whitish streaks.

2nd. A bluish-grey or pale brown, homogeneous stone, which however is seen under a lens to be distinctly crystalline.

3rd. A stone like the last, streaked with numerous parallel, slightly tortuous, white lines, of the thickness of hairs, which are ascertained to consist, when white, of quartz, and when green, of augite.

4th. A compact crystalline rock, banded in straight lines with innumerable layers of white and grey shades of colour, varying in width from the $\frac{1}{30}$th to the $\frac{1}{200}$th of an inch, and composed chiefly of felspar, also studded with minute black specks which consist of augite.

5th. A compact heavy rock like greenstone, not laminated, but with an irregular angular fracture, and abounding in crystals of glassy felspar. All these varieties pass into each other, and are fusible alike into a pale glass. They also intercalate with strata of obsidian, and are evidently connected with it in their origin. The latter also is often striated with layers of a felspathic rock, like an agate, or with rows of sphærulites.

Mr. Darwin observes, on the authority of Von Kobell, to which he might have added that of Abich, that whilst trachyte contains only from 65 to 69 per cent. of silica, pearlstone contains 75·6; obsidian 76; marekanite 79·2, and sphærulites about the same; so that the formation of thin layers of glassy and compact matter seems to result from a process of segregation

* Chapter on the Lipari Islands. † Volcanic Islands.

taking place in the mass, by which a larger amount of silica is determined to particular parts, and a different composition, as well as a different mineralogical character, are imparted to the several layers.

Now the lamination of trachytic and of other rocks of igneous origin may arise from the same cause, that cause being, in Mr. Darwin's opinion, a stretching of the portions of the mass whilst slowly flowing onwards in a pasty condition. It is evident that a viscid fluid flowing down a declivity would meet with less obstruction from friction towards the centre of the mass than where it touched the walls: hence these several parts of the mass would move with unequal velocity, and consequently a separation into layers would be occasioned.

The same effect, in short, would take place in a melted mass of lava or obsidian as in a glacier, which, as Professor J. Forbes has ingeniously shown, exhibits a laminated structure, in consequence of the separation of its parts whilst running down an inclined plane, owing to the retardation caused by an adhesion of its external portions to the rock on which it rested*.

It might be expected that crystallization should commence along the lines of separation rather than in the interior of the mass, space being allowed between the seams for the forms peculiar to the mineral to develope themselves, just as we find the finest crystals to be produced in drusy cavities.

The alternation therefore of vitreous and compact layers seems to result from a partial process of devitrification taking place in the fused mass, and it may assist our understanding of the subject, if we consider what are the causes by which this process is favoured.

Now it must be recollected, that in every glass whilst in a state of fusion two antagonist forces are at work, namely the attraction of aggregation, which tends to draw together the crystals of earthy silicates that may be formed, from the first moment at which the heat is diminished below the point of their fusion, and the chemical affinity subsisting between these crystals and the alkaline silicate with which they are intermixed, which latter, so long as it remains liquid from heat, has the same tendency to hold the earthy silicates in a state of uniform

* Travels through the Alps, p. 157 *et seq.*

diffusion, which water has to retain saline substances in solution. But from the moment that the attraction of aggregation between the crystals predominates, so that they collect around certain centres, the process of devitrification will commence, which may either be imperfect when a portion continues in the form of glass, or perfect when the whole has passed into a crystalline condition.

Now two circumstances may be pointed out by which this devitrifying process is promoted:—the first, the volatility which belongs at a high temperature to the alkalies, owing to which they will be slowly separated from their combinations, and the silica united with them will be left free; the second, the different degrees of fusibility appertaining to the several minerals produced, in consequence of which they will be detached one from the other in a greater or less degree, according to the length of time occupied in passing from one degree of temperature to another.

The former cause operates in artificial glasses, and probably in subaërial volcanic products, and is exemplified in the crust of opake matter which frequently forms on the surface of glass when it has been kept long exposed to heat—the latter in submarine volcanic products, where, for reasons which will be stated presently, the rate of cooling will be extremely slow.

Hence we may account for the difference between the brittleness and sharpness of fracture which belong to glassy lavas, and the toughness and difficult frangibility which characterize those of a stony description, the latter, even where they present to the eye an homogeneous appearance, being, as has been already stated, made up of a number of minute crystals of at least two different species, interlacing each other in every possible way, and thus giving compactness to the aggregate.

Now, in accordance with the above principles, let us suppose this same process of cooling to go on at a still slower rate, so that not only minute crystals of felspar and of augite should be formed, as in lavas of the ordinary kind, or of a zeolitic mineral, together with augite and magnetic iron, as in basalt, but so that, in consequence of the longer-continued fluidity of the mass, the minute crystals of each mineral should be enabled to cluster round certain nuclei, so as to form aggregates of appreciable dimensions; and let us further suppose,

that owing to the length of time occupied in passing through a limited range of temperature, arising either from the dimensions of the mass itself, or from its being surrounded by non-conducting substances, the crystals of the least fusible mineral should arrange themselves in different parts of the mass, before those of the more fusible ones became consolidated,—and we may readily imagine that, under such circumstances, a still further segregation of the materials might take place, and greenstone or porphyry be produced. In short, the several stages of the process appear to be nearly as follows:—

1st, That of a perfect glass, where the particles are throughout so regularly disposed, as to create no perceptible obstruction to the rays of light by attracting them in their passage through more in one direction than in another. With this, any degree of crystallization is obviously incompatible; and as the proportions of the ingredients must be definite, its existence can scarcely be looked for except amongst artificial compounds.

2nd, That of a substance like obsidian, where the vitreous character exists, although the transparency is destroyed owing to the intermixture of minute particles of opake bodies diffused through the mass, the proportions not being accurately adjusted, and the whole not being held in perfect solution by the alkaline silicate.

3rd, The state of ordinary lavas, in which a partial segregation of parts has taken place, so that the whole consists in the main of an aggregate of minute crystals of labradorite and augite, but where nevertheless the fracture at least shows, that the process of cooling has been too rapid to deprive the mass altogether of its vitreous character.

4th, The condition of basalt, which possesses a stony aspect and fracture, but coupled with an homogeneous appearance, owing to the intimate mixture subsisting between the minute crystals of augite, zeolite, and magnetic iron, one with the other.

5th, Greenstone, porphyries, &c., where the several minerals are sufficiently distinct, and of dimensions large enough to be distinguishable by the eye, so that the rock composed of them is said to be granular.

It remains to be shown why the three former descriptions of

igneous products should be produced under the ordinary pressure of the atmosphere, and the latter chiefly under water.

Now it will not be difficult to assign reasons, why, although a body of shallow water, from the more rapid cooling it would occasion, is likely to favour the formation of vitreous products even more remarkably than that exposure to the atmosphere which subaërial lavas undergo; yet deep water will possess the opposite tendency so completely, that we ought to meet among submarine lavas few substances of this description, except where the material has been ejected in thin streams into the fissures of a rock, possessing a different temperature, and therefore capable of robbing it of its heat in a rapid manner.

In order to understand this, we need only recollect that the cooling agency of water under ordinary circumstances is owing, not to its being a good conductor of caloric, but to the circulation induced in the strata of that fluid when heat is applied to it.

This circulation is effected in two ways: in some degree by the heated particles of water at bottom becoming specifically lighter, and consequently displacing those above; but in a still greater degree, owing to the absorption and subsequent disengagement of caloric, caused by the conversion of successive portions of water into steam, and their return to their original condition, when they come into contact with their supernatant liquor.

Now it seems almost a corollary from the laws established by Sir James Hall and others, that at the bottom of the ocean none of the water could be converted into steam; for if, as this writer infers, the pressure was sufficient to preserve water existing in the very midst of the lava (where the heat must be supposed to be at its maximum) in a liquid form, still more completely would it prevent that, which was incumbent on the heated mass, from assuming a gaseous condition in consequence of the heat communicated from below. It seems probable therefore that, as water is in itself a slow conductor of heat, the cooling of submarine lavas ought to proceed still more leisurely than that of subaërial ones is found to do, and hence that their component parts would remain for a still longer time in that intermediate condition between fluidity and solidity, during which, as Mr. Gregory Watt and others

have satisfactorily shown, the particles, released from the controlling power of cohesive attraction, and yet brought within distances favourable to the play of their mutual affinities, enter most readily into new combinations, and assume those crystalline arrangements which are natural to them.

Perhaps likewise the superior density of submarine lavas, the general absence of cells, and their not sending forth to the same extent those emanations of gaseous matter which appear to proceed from modern currents, might contribute to the same effect by still further prolonging the period of cooling.

There is also a principle in physics, of late very beautifully illustrated by M. Boutigny of Paris*, which may be applied to the elucidation of the cause of the slow cooling of submarine lavas.

This is the repulsion exerted by any body possessing a high temperature for a liquid placed upon its surface, which is such as to remove the latter in a great degree beyond the limits within which it would receive the heat transmitted. Thus, if a drop of water be projected upon a red-hot plate, it does not evaporate, but rolls about in drops over the surface of the heated body, acquiring a temperature of no more than 96°, until the plate cools down to a low brown-red heat, when the ordinary process of evaporation commences.

I have already alluded to this principle in page 288, in endeavouring to account for the circumstances attending the fatal explosion, which took place after a certain interval upon the entrance of a stream of lava into a small lake situated at the foot of Mount Etna.

Now let us apply this to the case of a stream of lava poured forth at the bottom of a body of water deep enough to control by its pressure the escape of vapour. Would not, under such circumstances, the progress of refrigeration be retarded by the repulsion exerted against the lower surface of the water by the incandescent matter, and by the interposition of a stratum of highly condensed steam, which in its confined state is known to be one of the worst possible conductors of caloric?

The same considerations may explain the prismatic structure belonging to many traps, which I have laboured to trace

* See the British Association Reports, vol. xiv. p. 27, Abstracts.

to that tendency to form spheroidal concretions, which is naturally assumed by such rocks on being allowed to cool slowly. Instances of this same structure are stated to occur amongst modern volcanic formations; by Mr. Scrope, in the interior of the crater of Vesuvius, as displayed in 1822; by Breislac and others in the lower portions of a lava-bed at Torre del Greco. It is certain however that such cases are rare, and that those igneous rocks of recent origin, in which an approach to such a structure is observable, appear for the most part to have derived it from the contraction occasioned by sudden cooling, rather than from the mutual pressure of spheroidal concretions taking place during a more gradual one.

Such are the columns of lava worked into millstones at Niedermennig near Andernach, which manifest their real origin by gradually approximating more and more, until at a certain depth they become united into one continuous mass. Such also are the rude columns observed near Torre del Greco, belonging to a bed of lava that had flowed into the sea, the result evidently of the rapid cooling thereby occasioned; and in another instance from the same locality, in which, as Mr. Lyell observes, "the rock may rather be said to be divided into numerous perpendicular fissures, than to be prismatic, although the same picturesque effect is produced. In the lava-currents of Central France, (those of the Vivarais in particular,) the uppermost portion, often forty feet or more in thickness, is an amorphous mass passing downwards into lava irregularly prismatic; and under this there is a foundation of regular and vertical columns, in that part of the current which must have cooled most slowly. But the lavas last mentioned are often 100 feet or more in thickness, and we cannot expect to discover the same phænomenon in the shallow currents of Vesuvius, although it may be looked for in modern streams in Iceland, which exceed even those of ancient France in volume."

Now the greater frequency of prismatic rocks in submarine than in subaërial volcanos is explained, by reflecting, that the slow cooling essential to that structure,—which in the latter is accidentally, or in a few cases, brought about by the remarkable thickness of the mass superincumbent, and that only in the lower portions of the bed,—is caused in the former

throughout by the vast pressure of the ocean above, whatever may be the supposed thickness of the bed itself.

With regard to the next point to be considered, namely the absence of craters, and the greater frequency of dykes in trap rocks, it must be admitted, that we are rather unfavourably circumstanced in order to draw a correct comparison between these and more recent volcanic products in the latter particulars. The craters of submarine volcanos, when composed of loose fragments, would be exactly the portions most likely to have been swept away by the currents of the ocean or other causes; whilst if they consisted of lavas, they might indeed remain, and yet all vestiges of their original configuration be obliterated by the rocks superimposed.

It would be rash therefore to assert that craters never have existed, because we do not discover any traces of them at present. On the other hand, it is only where accidental circumstances reveal to us the internal structure of a modern volcano that we can expect to find dykes, and there we do occasionally meet with them. Thus they are well known to exist on the sides of the old crater of Monte Somma, and Mr. Lyell has noticed the same in that of Vesuvius at present. Indeed they can hardly fail to occur when a body of liquid lava rises up into a crater, the rocks of which, owing to previous cooling, have become cracked or fissured.

In order however fairly to compare together the action of volcanos of different ages in this respect, we ought to refer to sections of some modern volcanic mountain, taken at a distance from the crater, of which some of the Lipari islands afford us good examples *, as also does the Val del Bove in Etna, described by Mr. Lyell †.

There we shall see dykes, which, though mineralogically resembling modern lavas, correspond, in their relation to the contiguous rocks, to those described by Dr. Macculloch in his *Western Islands* as running for a considerable space parallel to the strata, though originating in some great mass of trap underneath.

Nevertheless, although it is impossible by a direct appeal to facts to establish beyond the reach of cavil the greater fre-

* See pp. 249, 250, 252. † See pp. 276, 277.

quency of dykes amongst submarine volcanos, yet probability is certainly in favour of such an assumption.

"If volcanic forces," remarks Professor Sedgwick*, "ever have acted on a great scale upon unbroken and nearly horizontal strata, especially while such strata were under the pressure of the sea, the formation of tabular and vertical masses of lava appears a natural consequence of such action. Where, on the contrary, the pressure of the sea is removed, and the crust of the earth is broken through, volcanic fluids will find a ready escape, eruptions of lava will be confined to one spot, and the operations will be of a class altogether different."

The admission that trap rocks are lavas, tends very much to enlarge our ideas with respect to the extent of volcanic action at different periods.

From the occurrence of these products in connexion with every secondary formation, from the earliest down to the most recent, the chalk, it might be concluded that volcanic action had taken place during every one of these successive periods; but except when they can be proved to stand in the relation of beds interposed between the strata, such an inference would not be warranted.

Let us take, for example, the oldest rock with which any considerable mass of trap is associated in Great Britain, namely the carboniferous system of the northern counties, and that in the neighbourhood of Glasgow and Edinburgh.

The former of these, namely the coal-field of Northumberland, is associated with many very remarkable dykes, overlying masses, and apparent beds of trap; but the most considerable of the latter, the great Whin-sill, which is seen arranged conformably with the carboniferous limestone of Teesdale and the northern limestones of Northumberland, has been pronounced by Professor Sedgwick to be in fact a stupendous dyke, or collection of dykes, which was injected laterally between the strata. He however is inclined to refer the injection of this, as well as of the majority of the trap rocks of that neighbourhood, to a period antecedent to the magnesian limestone. Mr. Hutton and Mr. John Phillips

* Geology of High Teesdale.

differ from the Professor in their view of the origin of the Whin-sill, regarding it as in great measure formed by periodical submarine eruptions of lava, which took place at intervals during the deposition of the carboniferous strata with which it is associated. On either supposition, therefore, much of this extensive basaltic formation is allowed to be of a date as ancient as that of the carboniferous rocks themselves.

The trap rocks of Staffordshire, on the contrary, constitute overlying masses, which may either be contemporaneous with the coal-measures on which they rest, or may have been of a date much posterior.

Lastly, the trap rocks near Glasgow are so connected with those of the Western Islands, as the latter again are with those of the county of Antrim, which are posterior to the chalk, that we should be led to assign a much later epoch to their ejection, and likewise perhaps to extend the same inference to those in the vicinity of Edinburgh.

Thus we have three cases brought together, in which trap rocks are associated with the same system of rocks; the one of which is of a date antecedent to the magnesian limestone, or at latest contemporaneous with it, the third of the same age as the chalk, and the second doubtful.

In Derbyshire we meet with an apparent alternation of beds of trap called toadstone, which are more generally amygdaloidal, but occasionally compact, with the carboniferous limestone formation. But before we absolutely decide that the two are contemporaneous, it would be necessary to establish more completely than has yet been done, that they are conformable. If this be not the case, they may have been ejected long subsequently. On this subject however we expect to be enlightened shortly by the researches of Professor John Phillips.

The most extensive however, and in all respects the most interesting system of trap rocks found within the compass of the United Kingdom, is that which occurs in the Western Islands of Scotland, and which appears to be continued on through the county of Antrim in Ireland.

It is interesting, not only from the numerous sections which its situation near the coast supplies, but likewise from the circumstance that it is not mixed up, as those in other

instances are, with the volcanic products of a later period, no remnant of the operations which occasioned it being discoverable, either by the existence of hot springs, emanations of carbonic acid, or even earthquakes of any remarkable kind, in the contiguous country.

It affords us therefore the means of comparing the effects of submarine volcanos with those of subaërial ones, and at the same time of inferring, on evidence as conclusive perhaps as the subject itself can ever admit of being adduced, that volcanic action has in some instances expended itself, or at least has periods of rest beyond comparison longer in some cases than in others. Now either of these suppositions seems more consistent with the chemical theory, which imagines a definite quantity of combustible materials to be present in particular situations, than with the opposite one, which conceives the existence of an unexhausted fountain of melted matter underneath, such as should either gush out continually, or at least flow at intervals more approaching to regularity.

The trap rocks of the Hebrides manifest themselves under all the forms which have before been alluded to; but it would seem, from the observations of Macculloch and others, that the apparent alternations which have been remarked between them and the rocks of the country are merely caused by dykes intruded laterally between the fissures of the strata. Hence we are only sure that a considerable part at least of these trap rocks is posterior to the most recent of the strata found associated with them, and the latter would appear, from the researches of Sir Roderick Murchison, to belong to the oolitic series.

But there is no evidence that they may not be much later; for the basalts of the Giant's Causeway, on the opposite coast of Ireland, intersect the chalk, and are therefore posterior to that formation.

It is true that Dr. Macculloch has shown, from the occurrence of trap nodules in a conglomerate rock of Kerrera, that trap rocks must have been formed at a much earlier period*; but as we cannot on any supposition refer the whole to this epoch, we are quite at liberty to adopt any inferences, to

* Western Islands, vol. ii. p. 114 *et seq.*

which the facts may appear to lead, with respect to the age of the principal portion of that found in the Hebrides.

Perhaps therefore the Wernerians were not altogether wrong in referring the great overlying masses of trap that they observed in Saxony and elsewhere to one epoch, and that the most recent which, in the then existing state of their ignorance with respect to tertiary rocks, they were able to recognise, designating them by the name of the *newest flœtz trap formation*; for although we may be compelled to acknowledge that these rocks are of several distinct periods, and that in a great majority of cases their date is uncertain, still it seems by no means improbable that the most extensive eruptions of submarine volcanos took place about the period just alluded to.

This is rendered more agreeable to analogy when we remark, that nowhere have more frequent manifestations of volcanic agency occurred, than either at a period contemporaneous with that to which we have supposed the trap rocks to belong, or at one immediately subsequent to it, that is, during the deposition of the different tertiary formations.

It is remarkable at least, that all the extinct volcanos, as well as all those now active, which have been as yet explored, may be traced up to this period; regarding, that is, as we have a right to do, the volcanic rocks of a district as emanating from the same focus of action.

Thus the lavas of the Val di Noto alternate with rocks which appear to be tertiary, as also do those of Auvergne, of Hungary, of Styria, and of the north of Italy; so that whether we set down the trap rocks of the Hebrides as contemporaneous with the tertiary formations, attributing their greater compactness to the depth of water under which they were ejected, and from which they may have since been upraised, or whether we prefer to consider them as produced somewhat earlier, still we shall find equal reason for concluding, that during the period comprised between the date of the deposition of the chalk and that of the creation of existing races of animals, circumstances were peculiarly favourable to the development of volcanic operations.

It is remarkable too, that trachyte, properly so called, seems almost confined to this intermediate period; for although

Humboldt speaks doubtfully as to the position of this rock in the New World, yet in the Old it is found in a number of instances posterior to some of the tertiary strata, and we know of no instance in which it is decidedly proved to be of greater antiquity, whilst its rarity amongst lavas of modern ejection would seem to show that it was not, under ordinary circumstances, a product of existing volcanos.

Whether this circumstance is to be regarded as the *cause* or the *effect* of that elevation of a large portion of our continents from the sea which is supposed to have taken place during this epoch*, it may be difficult to say, but it is certain that both events may be traced to nearly the same period; and hence we observe amongst volcanic rocks of this age, that singular intermixture of compact with cellular, of glassy with lithoid lavas, which at the same time that it affords the most decisive evidence of the igneous origin of trap, indicates the different circumstances under which these rocks were formed, sometimes under the pressure of water, and at other times elevated above it.

Accordingly, in the former edition of this work I ventured to distinguish volcanic products under three different heads, according to their respective epochs; and although this classification, like every other artificial one, may be expected in some instances to fail us, it will nevertheless facilitate our general understanding of the subject still to retain it.

The first class then includes those rocks which form the immediate subject of the present treatise, being produced by igneous action, under circumstances similar to those which present themselves before our eyes.

These will comprehend lavas or tephrines, obsidians, pumice, and more rarely trachytes—rocks which are generally more or less cellular, and having their cells seldom occupied by crystalline matter. Although a certain segregation of parts has taken place, so that distinct minerals exist in the mass, yet they have generally a fracture more approaching to the vitreous

* See the map in the second volume of Lyell's Principles of Geology, 1832, showing the extent of surface in Europe which has been covered by water since the commencement of the deposition of the oldest tertiary strata.

than appertains to trap rocks in general. Their other characters have been already sufficiently dwelt upon.

The second class of volcanic products exists chiefly associated with the tertiary class of formations, a large portion of which were deposited in lakes of fresh or salt water, of various degrees of depth, and having often dry land in their immediate vicinity.

The character of the volcanic rocks will therefore be influenced by the difference of depth in the water, and by being thrown out, sometimes under the sea, sometimes on dry land. When in the former condition they will be compact and stony, when in the latter cellular and vitreous, so that we may expect to find great variations in the characters which rocks of this age present, owing to differences in the above circumstances.

The older volcanic rocks of Auvergne, those of the Val di Noto in Sicily, those of Styria, and of the Venetian States, may be given as examples of this second class of products.

The third class comprehends those which are associated with all the other rocks anterior to the tertiary epoch, and are distinguished, as we have seen, by those characters which stamp them as submarine.

It would seem more probable that they have been ejected through the medium of *dykes* than of *craters*; not that dykes are wanting in modern volcanos, or that craters may not have existed at all periods at which there was land elevated above the level of the waters, but that it is most probable that under the pressure of the ocean, the molten flood would find its way upwards chiefly through narrow channels, which would remain filled by the matter thus injected into them.

If craters had existed, they would be effaced by the subsequent changes which the earth has undergone, and the only relic of them that met our observation would be seen in the dykes through which the lava passed before it reached the surface.

These dykes, it has been remarked, more commonly affect the substance of the contiguous rock than what are produced by modern volcanos.

Thus in the neighbourhood of basaltic dykes of this age, limestone is often converted into marble, claystone into flinty slate, and sandstone into jasper. Such changes would seem to require for their production something more than the common application of a heated body, for it is by no means so usual to find a rock altered in the parts which immediately support a *bed* of trap, as it is in those which are traversed by the very same material in the form of a *dyke*.

Perhaps indeed the action of a continued stream of melted matter, fresh from the focus of the volcano, might be expected to produce more decided effects upon the walls of the fissure traversed by it, than would be occasioned by a mass of the same spread out over the cool and damp surface of a rock; since the heat in the former case must be at once more considerable and continued for a longer period. Even the pressure exerted upon the contiguous surfaces by the matter injected through the rock may contribute in some degree to the same effect; and if there be really that distinction between dykes of older and younger formation which has been above hinted at, it may be possible to connect it with the diminished force with which the lava was propelled through the substance of the rock, when the resistance of the ocean above had been in great measure taken off.

In the case of the dykes of Monte Somma, which, as M. Necker remarks, have produced no change on the contiguous stratum, I should attribute more to the nature of the rock which they traverse, than to any difference in the material itself. It is natural to expect that the effect should be proportionate to the compactness of the former, and therefore that a stream of the same melted matter would produce a more decided alteration in passing through a bed of granite or limestone, than one of tuff or gravel.

But there is yet another extensive class of igneous rocks which cannot be referred to any one of the three divisions that have just been laid down. These are granites, and the other felspathic rocks of igneous, or so called *metamorphic* origin, which are found associated with them.

From a general sense of the marked difference between their characters and relations, and those of the rocks we have

been considering, geologists are agreed in designating them by the name of *plutonic*, confining the term *volcanic* to the acknowledged products of volcanos, whether active or extinct, subaërial or submarine.

As a proof that this line of demarcation is not an arbitrary or artificial one, I will shortly state some of the characters by which granitic rocks are clearly distinguished from the products of volcanos.

In granite then there is always an excess of silica beyond what is necessary to combine with the earthy and alkaline bases present. These accordingly are united with the largest quantity of silicic acid for which they have an affinity, forming generally a felspathic mineral with three atoms of acid, namely either orthoclase or albite; and in conjunction with this felspar, and with a portion of mica, is a considerable amount of silica existing as quartz, uncombined with any other element.

2ndly. The bodies united to silica in granite are generally potass, soda and alumina; lime and magnesia being either absent, or appearing only in minute quantities.

3rdly. If iron be present, it is commonly in the state of peroxide, seeming to show that the mass had not been exposed to hydrogen or to any other deoxidizing agent.

4thly. The minerals of which it is made up are for the most part distinct, and often occur in large crystals or concretions. Hence the granular structure from which it has derived its name.

5thly. The rock is often intersected by mineral veins, containing a number of distinct substances that have separated probably by infiltration from the mass.

6thly. Although it sometimes passes into a rock in which hornblende takes the place of mica, yet augite is rarely present, at least as a predominant ingredient.

And lastly, although it has been found intruding itself into, and overlying rocks of a very recent date, yet it never has been known to be erupted in the open air in the manner in which volcanic rocks make their appearance.

The latter, on the contrary, show a regular series of gradations from trachytic porphyry, which is the nearest approach to granite, and which still contains a large proportion of uncombined silica, to trachyte properly so called, in which the whole

of the silica is united to some basis or other, and generally exists combined in the proportion of one atom only instead of three.

From thence there are various gradations, connecting trachyte with greenstone and basalt, owing to the successive additions of lime and magnesia to the alumina, potass and soda present in the foregoing products, and determining the formation of those species of felspar which contain the smallest amount of silica and the largest of lime, together with a gradually increasing quantity of augite and magnetic iron, in which that metal exists partially reduced to the state of a protoxide.

These rocks exhibit every gradation from a granular structure analogous to that of granite, which is developed in those products that have cooled slowly, to the vitreous condition which is sometimes seen amongst subaërial lavas.

Although they intrude themselves into rocks of all ages, there seems no clear evidence of their having been produced during the primordial condition of our planet, as was the case with granite, nor do they contain mineral veins, except in a few rare instances, where they make the nearest approach to granite.

Other distinctions may be easily gathered from the elaborate researches of Professor Keilhau, which, although they may not establish any conclusion so paradoxical as that of the production of granite being independent of igneous action altogether, show at least that the circumstances under which this rock was produced must have been widely different from those which determined the formation of modern igneous products.

What these circumstances might be, I have ventured to hint in the course of the preceding chapter; but conscious of the obscurity that still hangs over the subject, an obscurity which it will require many years more of patient investigation even partially to remove, I am now chiefly solicitous that the admission of the igneous origin of granite may not induce geologists to consider their labours at an end, or tempt them so far to overlook the marked distinctions that exist between these several products, as to assume, without further examination, that the causes which operate in the production of volcanos have been also instrumental in building up the granitic skeleton of our planet.

CHAPTER XLI.

FINAL CAUSES OF VOLCANOS.

Volcanos act as safety-valves by which earthquakes are prevented—as agents in elevating chains of mountains—are instrumental in supplying plants with carbonic acid—and with ammonia.—Formation of ammonia in the interior of the earth.—Volcanos also furnish the inorganic constituents necessary for the food of plants—and in a condition in which they can be slowly taken up—render phosphate of lime soluble in water—and evolve it from the depths of the earth—return back to the surface the water which finds its way into the bowels of the earth—contribute towards the formation of mineral veins.—Their influence in communicating fertility shown in the case of the Campagna about Naples.—Desolation caused by an eruption not permanent.

Having now completed my review of the various phænomena exhibited by volcanos in their various phases of activity, and endeavoured to refer them, with as much probability as the nature of the case admits, to a certain condition of things still existing in the internal mass of our planet, I shall proceed in the last place to consider what great purposes in the economy of Nature may be fulfilled by the operations that have been brought under our notice.

In the first place, then, it may be remarked, that whatever may have been the end, for the sake of which an accumulation of inflammable materials in the interior of our globe was ordained, their existence there, under circumstances which admitted of their undergoing from time to time inflammation, may teach us to regard the production of volcanos not only a natural consequence, but even a useful provision.

They are the chimneys, or rather the safety-valves, by which elastic matters are permitted to discharge themselves, without causing too great a strain upon the superficial strata.

Where they do not exist, they give place to a visitation of a much more destructive nature; for those who have experienced a volcano and an earthquake will readily testify, that the consequences of the one are by no comparison lighter and less portentous than those of the other.

The same country is indeed often exposed to this double visitation; but that the existence of the volcano is even there a source of good, appears from the fact that the most terrible effects are felt at a certain distance from the orifice, although the focus of the action is probably not far removed from the latter.

The agitations which took place during six years at Lancerote likewise show, how much more destructive the effects of subterranean fire appear to be where no permanent vent is established.

But we are not driven in the case before us to regard volcanos merely as a remedy for a greater evil,—an expedient for preventing those heavier calamities which would have resulted from the confinement of so tremendous a force.

Without presuming to divine more of the designs of Providence in the arrangements of the physical universe, than is manifested to us within the minute point of space and of time that lies open to our observation, I may remark, that the elevatory forces set in motion by volcanic action appear to act a most important part in preparing the condition of the earth's surface for the reception of man and other animals. Where they have not operated, as appears to be the case in the centre of Australasia, the level surface of the land, receiving no fertilizing streams from the mountains, and intersected by no arms of the sea, or extensive lakes, by which a communication with other parts of the globe can be maintained, seems abandoned to hopeless sterility, and becomes indeed almost inapproachable by human enterprise.

Were volcanic forces ever to become rife within this vast continent,—were a range of Cordilleras to stretch across its now desolate surface, a new character would be imparted to its physiognomy, and the dull uniformity of its outline be succeeded by the smiling aspect of a European landscape.

But without dwelling upon the beneficial changes brought about by volcanos in elevating large tracts of continent, and in producing probably those chains of mountains which exercise so important an influence upon the meteorological condition of whole regions in their vicinity, I may point out cer-

tain chemical uses they subserve, not less essential to organic life, and perhaps more distinctly referable to their agency.

I may remark in the first place, that the chemical properties which distinguish the elements of bodies, appear as definite and unalterable as the general laws which operate upon all matter whatsoever. There is no more reason to suppose that gold has become more heavy, or iron more oxidisable since it was first created, than that the attraction of gravitation which draws together the particles of every kind of matter has varied in intensity since the beginning of time. Moreover we have reason to believe that the proximate principles of organic bodies are equally unchangeable, and that, even to the minute quantities of inorganic matter which enter into their composition, though consisting perhaps of only $\frac{1}{100}$th or even $\frac{1}{1000}$th part of the whole bulk, no change either has or can take place from that which belonged to it originally.

Now these general principles once admitted, lead to some important conclusions.

They establish, in the first place, the absolute dependence of living bodies upon a constant and due supply of all, even to the minutest, of the ingredients which enter into their constitution; for they show that these, if wanting, can neither be generated by the vital functions of the part, nor made up for by the substitution of any other element that may happen to present itself: and as the health and even the existence of organic substances would be interfered with in the event of an excessive supply of some of the ingredients which they require, as by an excess of alkali, of certain salts, of carbonic acid, or of ammonia, it is equally necessary that whilst the latter are everywhere present, they should be never in too large a quantity.

Let us see how this great end is accomplished by Nature with respect to the supply of the most important of these—I mean carbonic acid.

It has been wisely arranged that plants can exist in an atmosphere more impregnated with carbonic acid than animals can do, and that amongst plants, those kinds which approach nearest in form and organization to the ones which lived during the period of the coal formation, are most tolerant of an excess of this ingredient. Nevertheless there is doubtless

a point beyond which the addition of carbonic acid to the air could not proceed without the extinction of every kind of life, and hence it is probable that the whole amount of carbon which is now fixed in animals and vegetables, dead or alive, in our coal basins as well as in our forests, was never at any one time present as carbonic acid in the atmosphere.

There seems a much greater probability that it was gradually supplied, in proportion to the demand, by volcanos, which, as we have seen, are at the present time vomiting forth very large quantities of this gas, even at times when to an ordinary observer they appear to be extinguished. Whilst coral animals and mollusca of various kinds are continually adding to the amount of carbonate of lime at the bottom of what is now the sea, but which will one day doubtless form dry land, volcanos on the other hand are employed in redressing the balance, by expelling the carbonic acid from limestones of older date, and forming rocks of silicate of lime in the place of those composed of carbonate.

It may appear a bolder speculation to extend the same inference to the case of ammonia, yet I have the authority of one of the first of modern chemists for asserting, that this body cannot be formed by the direct union of its elements upon the surface of the earth, and that nevertheless through its medium the whole of the nitrogen present in plants, and transmitted by them to the animals they nourish, finds its way into the system of both.

That ammonia is disengaged from volcanos often in large quantities is certain; that one of its ingredients, nitrogen, penetrates to the depths at which volcanic processes are carried on, follows necessarily from its constant evolution from thermal springs; that hydrogen, its other ingredient, is present also, will hardly admit of dispute; and that nothing but the force of their mutual elasticity prevents these two elements from combining, seems implied from the difficulty of decomposing them when once united. Is it not then a tenable hypothesis, that the great pressure which exists in the interior of the earth may effect that union which cannot be brought about near the surface, especially when it is recollected that the hydrogen would be in a nascent condition, so that nothing

more than the elasticity of the other element would require to be overcome?

Supposing this question to be answered in the affirmative, no apology will be wanting for here introducing those remarks upon this part of the subject, which were published in the year 1841, in some Lectures on Agriculture originally delivered before the University of Oxford.

Startling, I remarked, as the position may appear, yet fortified as I am on this point by the authority of Baron Liebig, I shall not scruple to suggest as a matter at least of probable conjecture, that every particle of carbon as well as of nitrogen which enters into the constitution of the plants and animals, either now existing, or which have existed since the beginning of time, may have been originally evolved from the interior of the globe.

The only mode that suggests itself by which we can escape from this conclusion consists in supposing, first, that when it first pleased the Almighty to call plants into existence, He at once overspread the globe with them, without availing himself of the operation of secondary causes to bring about their dissemination; secondly, that the amount of carbon and of nitrogen contained in the plants created sufficed for supplying the entire animal kingdom, in proportion as it extended itself, with the organic matter which it would require; thirdly, that no increase to the collective amount of the animal and of the vegetable matter in existence has taken place from the first period at which they were called into being up to the present time.

Unless all these three postulates be assumed, it seems difficult not to attribute to gases evolved from inorganic sources, the first origin of those organic matters of which both plants and animals consist.

Now it will perhaps appear to some of my readers futile, and even almost presumptuous, to go back, as it were, to the dawn of creation, and to speculate on events that may have occurred at the first commencement of organic life.

Nevertheless, I may be permitted to observe thus much, namely, that analogy seems to favour the supposition of each species of plant having been originally formed in one particular locality*, from whence it spread itself gradually over a certain area, rather than that the

* Mr. Lyell proposes the following hypothesis, as being reconcilable with known facts, viz. "that each species may have had its origin in a single pair or individual, where an individual was sufficient, and that species may have been created in succession, at such times and in such places as to enable them to multiply and endure for an appointed period, and occupy an appointed space on the globe."—*Principles of Geology*, vol. ii. chap. 8.

earth was at once, by the fiat of the Almighty, covered with vegetation in the manner we at present behold it.

The human race, as we are informed by the highest authority, is descended from a single pair, and the distribution of plants and animals, over a certain definite area, would seem to imply that the same was the general law.

Analogy would also lead us to suspect, that the extension of species over the earth originally took place on the same plan on which it is conducted at present, when a new island starts up in the midst of the ocean, produced either by a coral reef or by volcanic elevation. In these cases we do not find the whole surface at once overspread with plants, but we can trace the gradual progress of vegetation, from the chance introduction, of a single seed perhaps, of each species, floated to it by currents or wafted by winds.

Nor indeed does it seem probable, that a preternatural cause should have operated in covering the earth with plants, when natural ones are supposed to have been instrumental in the formation of the strata upon which they grew.

Since these latter have been built up gradually, through the successive accumulation of mineral and organic deposits, in which act Omnipotence did not directly interpose, we should be disposed to refer the full development of the former to a slow dissemination of individuals, in conformity with natural laws, and to ascribe to the immediate hand of the Deity only the first introduction of each species. Such an exertion of creative power, as is implied by suddenly calling into existence all the plants of a particular period, seems the more improbable, when we recollect that it must have been repeated at several successive epochs, since we cannot suppose that the whole globe would have been in an equally forward condition, so as to be ready at the same moment for the reception of a redundant vegetation.

If however we were to grant, that the whole of the primary vegetation of the globe had started into being at once, so soon as the conditions of the earth's surface admitted, we should be bound to suppose the character of the plants analogous, rather to those existing in countries not yet brought under the dominion of man, than to those of cultivated districts.

Now, it is to be remarked, that the plants most useful to the higher classes of animals, inasmuch as they afford the greatest abundance of nourishment, are comparatively rare in a wild condition, and when they occur, are generally deficient in those principles on which their value as articles of food depends.

The forests, which under such circumstances cover so large a portion of the surface, contain but a small amount of nitrogen, for

woody fibre, which constitutes the greater part of their bulk, is wholly destitute of that principle.

The Cruciferæ, the different species of cereal Grasses, and other plants rich in nitrogen, require for their full development animal manure, and therefore, if they had come into being at all at this early period, must have been stunted in their growth and limited in their distribution.

Hence it may be fairly doubted, whether the whole amount of the plants, which existed at one time on the surface of the globe, would have furnished azote enough for the animals of any given period.

Thirdly, it seems reasonable to suppose that civilization has, upon the whole, increased the aggregate of animal life, as well as that of such vegetables as contain the largest quantity of nutritious matter.

I am aware how difficult it would be to establish this last position in a manner perfectly unexceptionable, because the progress of human society is attended by a corresponding diminution in the amount of those animals and of those plants which are not dependent on man, and it seems impossible to strike a correct balance between the effects attributable to these two counteracting causes.

Nevertheless, the following considerations may perhaps be allowed to favour the opinion which I have been advocating.

There can be little doubt, that within the area embraced by culture, the amount of nutritious matter goes on increasing with the care bestowed upon the land, and that the number of animals maintained is in consequence proportionably increased.

This will be the case on a well-managed farm, even where (being situated at a distance from a town) it consumes no more manure than is obtained on the premises. At the end of a century the live-stock may be increased, the crops may be more abundant than they were at the beginning, and yet every year a large quantity of carbon and nitrogen will have been carried off in the shape of the corn and cattle sold.

Whence does this excess of carbon and of nitrogen then proceed? If from the decomposition of animals and vegetables extraneous to the farm, other portions of the globe must suffer in proportion to what is gained by those in cultivation, and hence the vegetation, as well as the amount of animal life, in regions which continue in a state of nature, will decrease in proportion to the increase of those brought under subjection to man.

But we have not the slightest reason to imagine such to be the case, nor is there any ground for believing, that plants in a wild condition are unable to compete with cultivated ones, in the power of supplying themselves with those principles which are necessary

for their existence; although it be true that man, by selecting for culture such as afford him the greatest amount of nutriment, causes more nitrogen to be abstracted from the air than would otherwise happen.

But what appears to me the most decisive objection yet remains to be stated.

Once grant with Liebig, that the nitrogen which plants possess can only be obtained by them through the decomposition of ammonia, and it will follow, that unless this gas be supplied from the interior of the globe, the quantity of organic matter, into which this principle enters as a component part, will be undergoing a continual diminution.

For we know of no natural processes taking place on the surface of the globe which generate ammonia, excepting those connected with animal and vegetable decomposition; whilst there are many, such as the combustion of various organic substances, which, by resolving bodies containing nitrogen into their constituent elements, would have diminished the aggregate amount of them which might have formerly existed.

Some compensating process therefore is clearly required, and that, if I mistake not, is the disengagement of ammoniacal gas from the interior of the globe.

Possibly however it may be suggested as another alternative, that the quantity of these two gases which would be required for the subsistence of the whole vegetable and the whole animal kingdom when first called into being, and likewise all that which might be necessary to supply the loss of ammonia occasioned by combustion, &c. through all succeeding ages, might have been ready prepared in the atmosphere prior to their creation.

But, independently of the difficulty of conceiving, in the case of ammonia, by what means the particles of hydrogen and of nitrogen could have been brought to combine on the surface of the globe, without having been previously deprived of their elastic condition, those who propound this hypothesis ought to be prepared to show, that an atmosphere, charged with the gases in question to the extent which is assumed, would not have been fatal to beings possessing an organization analogous to that of the existing races.

To confine ourselves to ammonia, Drs. Turner and Christison have shown, that less than $\frac{1}{100}$th part of this gas, introduced into air, caused, in ten hours, a shrivelling and drooping of the leaves of a plant, and its subsequent death.

It may be doubted therefore whether even $\frac{1}{1000}$th part would not be too powerful a dose for the continuance of the healthy functions

of the vegetable world, if permanently present, considering that the juices of the plant, and the moisture of the earth in which it grows, would be continually drawing from the atmosphere a constituent so soluble in water, and thus presenting it in a state of much greater concentration.

What the amount of nitrogen existing in all the plants and animals, either living or preserved from decay, throughout the globe may be, it would be extremely difficult to determine; but admitting Liebig's principles, it will follow that the amount of ammonia actually existing in the air will represent the average quantity which at each moment of time is disengaged from the organic matter of all kinds undergoing decomposition.

The quantity of ammonia present in the atmosphere, under existing circumstances, will therefore bear the same ratio to that required for the maintenance of the whole animal and vegetable creation together taken, as the amount of organic matter, at any given time undergoing decomposition, does to that in a state of life, or of preservation from decay.

Now it may be collected, I think, from Liebig's statements, that a pound of rain-water sometimes contains as much as one-fourth of a grain of ammonia, or about $\frac{1}{30000}$th part. Could we tell therefore the proportion which the quantity of organic matter undergoing decay bears to that in a living or sound condition, we might obtain the means of estimating whether the whole amount of nitrogen existing throughout the globe, if it were at once diffused through the atmosphere, would not communicate to it deleterious qualities.

I have said that the *onus probandi* ought to rest with those who propound the last-mentioned hypothesis, because undoubtedly a presumption would seem to exist in favour of the view for which I have myself contended, from our having direct evidence that the evolution of these gases from the interior of the globe is proceeding continually.

Hence it seems natural to attribute, to a phænomenon at once so constant and so general, some end in the economy of nature, and to suppose it to have been going on, like the volcanic processes which produce it, without interruption from the beginning of time.

Granting then, what upon Liebig's principles seems most consistent with analogy, namely that the ammonia, no less than the carbonic acid, which formed the food of the first plants, has been produced, not by processes of animal decay, but by such as were proceeding within the globe prior to the creation of living beings, the notion of a slow and continuous disengagement of both compounds, from the earliest period to the present time, will be received perhaps

as at least the most probable mode of accounting for their unfailing supply.

Whilst it relieves us from the difficulty of supposing the atmosphere surcharged with these gases at any one period, it suggests to us at the same time sublime and interesting views of the arrangements of the Deity, in thus having made all things subservient to one common end, and having ordained that the mighty Agents of destruction which exist in the bowels of the earth should minister, like the malignant Genii of some eastern fable, to the wants and necessities of the living beings which He has placed upon its surface.

These remarks however may appear to my readers somewhat too speculative and fanciful; let us turn then to certain other uses of volcanos which are of a more tangible and demonstrative character.

I have already remarked, that whatever is necessary for the constitution of organic principles, must be contained either in the earth or in the air with which the living body is in contact: but this is not all; they must be exhibited also in a soluble condition, so as to enter the delicate cells of the plant together with the sap.

Thus potass, soda, certain earthy phosphates, lime, magnesia, must be present wherever a healthy vegetation proceeds. Now some of these bodies are naturally insoluble in water, whilst others are dissolved with such readiness, that any conceivable supply of them, in their isolated condition, would be speedily carried off and find its way into the ocean. The first therefore must be rendered more soluble, the latter less so, than they are by themselves.

Now the manner in which Nature has availed herself of the instrumentality of volcanos to effect both these opposite purposes is equally beautiful and simple.

She has in the first place brought to the surface, in the form of lava and trachyte, vast masses of matter containing the alkalies, lime and magnesia, in what I have termed, in the lecture* before referred to, a *dormant* condition, that is, so united by the force of cohesion and of chemical affinity as not to be readily disengaged and carried off by water.

Where indeed these ingredients exist in a state approaching

* Bakerian Lecture, page 248.

to the vitreous, scarcely any length of time will be sufficient to decompose them; but it is remarkable, that in submarine lavas or traps such a condition does not exist, the slow cooling which has taken place in them giving time for the segregation of its elements, and for the formation of distinct mineral compounds.

Accordingly, as has been stated in a former part of this treatise, these products, as well as a considerable portion of stony lavas, are partially soluble in muriatic acid.

Now nature has provided, in the carbonic acid which is so copiously evolved from volcanos, and which consequently impregnates the springs in those very countries more particularly where volcanic products are found, an agent capable, as completely as muriatic acid, though more slowly, of acting upon these descriptions of rock, of separating the alkali and alkaline earths, and of presenting them to the vessels of plants in a condition in which they can be assimilated.

Thus every volcanic as well as every granitic rock contains a storehouse of alkali for the future exigencies of the vegetable world, whilst the former is also charged with those principles which are often wanting in granite, but which are no less essential to many plants,—I mean lime and magnesia.

Had the alkalies been present in the ground in beds or isolated masses, they would have been speedily washed away, and the vegetables that require them would by this time have been restricted to the immediate vicinity of the ocean.

In short, nature has in this instance adopted an expedient which a distinguished chemist of the present day attempted to imitate, in the manufacture of a manure in which the alkaline ingredient is rendered sparingly soluble by uniting it with carbonate of lime, and is thus prevented from being washed away by the rains before it is required for the uses of the plant.

The same agency has been called into play, for rendering certain principles soluble which by themselves would resist the action of water.

Thus, as I have stated in my Bakerian Lecture on the Rotation of Crops, published in the 'Philosophical Transactions' for 1845, and as has been since more fully shown by

Dumas* and by Dr. John Davy †, carbonic acid imparts to water the power of dissolving phosphate of lime, even enabling it to take up those minute portions of this substance, which, according to my own experiments, exist in the generality of secondary limestones.

Dr. Fownes ‡ has shown that phosphate of lime is present in many volcanic products §, so that although its immediate source at the present day may be the coverings of crustacea, the bones of animals, the earthy residue of the seeds of certain plants, which contribute to make up the aggregate of many secondary rocks, yet these animals and these plants must have originally obtained this necessary principle from the decomposition of volcanic products into the composition of which it entered, and along with which it was brought by igneous agency from the interior of the globe.

In short, volcanos appear to be the agents for bringing up to the surface those ingredients which lie deep within the bowels of the earth, and which might have been there for ever locked up, had it not been for its deep-seated and explosive energy.

There may be something fanciful in what I am next going to suggest, with regard to another end which volcanos may be conjectured to fulfil; yet if there be any truth in the idea, that the pressure of the ocean would be constantly forcing a certain portion of its waters through fissures into the interior of the earth, it would seem that there ought to be some compensating process, by which the ratio between the sea and land might be preserved unaltered.

This would perhaps be afforded by the action of volcanos, which restores to the surface just as much water as had been admitted to the spots at which the process is going on; for

* Comptes Rendus, Nov. 30, 1846.

† Proceedings of the Royal Society, April 22, 1847.

‡ On the Existence of Phosphoric Acid in Rocks of Igneous Origin, Phil. Trans. 1844.

§ The only known instance of an extensive bed of this mineral is that in Estremadura, examined by Captain Widdrington and myself. See Journ. Eng. Agric. Soc., vol. v. 1845.

although the first effect of the action may be to decompose that fluid into its constituents, yet the immediate consequence is, as we have seen, the disengagement of a large volume of sulphuretted hydrogen and sulphurous acid gases; so that by the action either of the latter fluid, or of atmospheric air upon the former, the whole of the hydrogen of the water, sooner or later, becomes re-united with oxygen. This indeed is *one* cause of the quantity of steam given out from the craters of all burning mountains.

One other use of volcanos may be suggested, although its full discussion must be here avoided, as carrying us too far into the wide and difficult subject of *metamorphic action*.

When however we reflect, that modern volcanic products appear entirely deficient in the rarer metals, and that the commoner ones, such as iron and copper, occur disseminated through their substance, instead of being collected into veins or nuclei, one cannot help conceiving, that one effect of the long-continued application of heat upon the older igneous formations of the globe might have been that of bringing about such a segregation of the ingredients, as has given rise to the formation of mineral veins, and to local accumulations of metallic matter.

If this be the case, we may regard volcanic agency as the appointed means, not only of conveying to the surface substances so serviceable to the uses of civilized man as those alluded to, but also of presenting them in that condition in which alone their existence could have been recognized, and their properties in the first instance made known to him.

Finally, with regard to the products of volcanic action, though, from the individual mischief they occasion, they can hardly be viewed by the inhabitants of the country overspread by them in any other light than as serious present calamities, they do not nevertheless deserve to be considered as permanent or unmixed evils, even in their effects upon the spots where they occur.

The fertility of many volcanic districts is proverbial, and it may be a question whether the free extrication of carbonic acid, possibly even of ammonia, from the ground in their

neighbourhood, may not exert a favourable influence upon the surrounding vegetation*.

All classical scholars recollect the luxuriance attributed to the lands of Campania, the "*vicina Vesevo arva jugo*," which in Pliny's time bore three crops in the year, being sown once with panic and twice with wheat; and yet when allowed to rest betwixt crops, produced spontaneously roses more fragrant than those which resulted from cultivation in other places—"*unde vulgo dictum*," says Pliny, "*plus apud Campanos unguenti, quam apud cæteros olei fieri.*"

Nor has this land, like much of that which is found in the newly-settled parts of America, lost its fertility by continued cropping, but at the present day, as of old, stands distinguished even in that highly famed region for the abundant returns which it yields to the husbandman.

"Quantum autem universas terras campus Campanus antecedit, tantum ipsum pars ejus, quæ Laboreæ vocantur, quem Phlegreum Græci appellant."

It seems probable, that the regular and general evolution of carbonic acid which appears to take place throughout this district,—for scarcely a pit can be sunk in any part of it which does not become filled with this gas to such an extent as to extinguish flame,—may contribute to this remarkable fertility, in no less a degree perhaps than the peculiar constitution of the soil which characterises it; but whatever share we may please to apportion to the one or the other of these causes, it must at least be admitted that volcanic agency is equally implied in them both.

It is indeed true, that something gloomy and depressing strikes us in the contemplation of a volcanic mountain, when we consider the cities it has overwhelmed, the fields it has reduced to desolation.

Yet if we do not adopt the notion once so prevalent with

* It may appear a homely comparison, but to liken small things with great, the analogy is complete between the arrangements of nature in supplying from below the gaseous materials which the crop requires for its growth, and the plan often adopted by the gardener, of placing in a vessel underneath the roots of a plant a body of animal manure, which by its exhalations communicates to it the very same principles.

respect to the speedy dissolution of our planet;—if, regarding the arrangements of the physical world designed with reference to long periods of time, we take up the more pleasing, as well as, I conceive, the more probable opinion, that a Globe which required so many ages to prepare for the accommodation of its present inhabitants is destined for many ages more to afford them a suitable abode*;—there is then a ground of consolation in the reflection, that the very lava which for so long a period has spread the most hopeless sterility over the ground it traverses, in process of years crumbles into the richest of soils; and that, if we take the case of the neighbourhood of Naples as that volcanic district with which we are best acquainted, the experience of what has happened before justifies a belief, that the inflammable materials which supply the fires of Vesuvius may ultimately be expended, and that the Mountain at some future period will return to the fertile condition which Martial describes as belonging to it, when not its slopes only, but its very heights, were covered with vineyards, and the spots surrounding the actual crater were considered the favourite resort of the Gods.

> Hic est pampineis viridis Vesuvius umbris,
>   Sparserat hic madidos nobilis uva lacus.
> Hæc loca, quam Nysæ colles plus Bacchus amavit,
>   Hoc nuper Satyri monte dedere choros;
> Hæc Veneris sedes, Lacedæmone gratior illi,
>   Hic locus Herculeo nomine clarus erat.

* The probable duration of the globe, or of its present inhabitants, is, I believe, an open question in theology, although the speedy extinction of one or both may have been in all ages a favourite topic with certain divines. The latter however may be reminded, that if their hearers cannot be deterred from vice, or incited to piety, by the prospect of their own inevitable dissolution, they are not likely to be much influenced by having put before them that of the world itself, which at any rate is much less certain, and probably vastly more distant.

ERRATA.

Page 17, note, *for* magnesia *read* manganese.
— 40, line 10, *for* unaccompanied *read* not accompanied.
— 71, line 3, *for* south *read* north.
— 213, line 19, *omit the words* otherwise than by electricity.
— 218, line 32, *for* which will be afterwards mentioned *read* which has just been mentioned.
— 512, line 6, *for* John *read* James.

APPENDIX.

ADDITIONAL NOTES.

Page 109.

On the Rhöngebirge.

NEVERTHELESS Leonhard, in the Description of the Rhöngebirge, published in his Zeitschrift für Mineralogie for 1827, seems to countenance the idea that a part at least of this chain is of modern, or as I should formerly have expressed it, of postdiluvial origin.

He speaks of the crater-shaped appearance of the neighbourhood of the Pferdekopf, which, he says, affords unequivocal traces of plutonic revolutions, and notices amongst the rocks masses of slaggy, felspathic minerals like those surrounding the Lake of Laach.

This chain of mountains seems therefore still likely to furnish a field for geological inquiry.

Page 150.

On the Theory of Dolomisation.

The most difficult point relating to the theory of dolomisation seems to be, that of determining the source from whence the magnesia present in the rock can have been derived.

In true dolomites, it must be recollected, this earth is not confusedly mixed up with the limestone, but occurs blended with it in atomic proportions, viz. one atom of carbonate of lime combined with one of carbonate of magnesia. Now I have found specimens of this material at Gerolstein in the Eifel (as stated in page 74) which are full of corallines, so that if the limestone had been converted into dolomite at any period subsequent to its original deposition, the intimate penetration of the magnesia which has taken place must have been effected by some process which did not obliterate the structure of the mass.

Moreover, in cases where the dolomite occurs at a distance from any igneous rock, or having beds of common limestone interposed between it and the latter, we should be obliged to suppose the sublimed magnesia to have diffused itself over a vast extent of rock, attaching itself to certain portions only, and leaving others, through which it must have passed, not only without uniting with, but even without producing any change in its progress through them.

Now, though I do not pretend, that in the present condition of our che-

mical knowledge we are able altogether to remove these difficulties, I conceive they may be diminished considerably, if we reject the idea that the magnesia has been derived from the volcanic rock to whose presence the dolomisation is attributed.

To imagine the magnesia to have been separated by heat from the minerals containing it with which the igneous formation is commonly charged, would seem to involve the supposition, that in the neighbourhood of dolomitic rocks such minerals are either wanting or deficient, which has never yet been pretended; and if we assume the heat of volcanos to be capable of subliming magnesia in the quantities required for this hypothesis, we should look for the earth itself amongst the products commonly exhaled from the craters of existing volcanos, and even from recently ejected and incandescent lavas.

If therefore we can derive the magnesia from the original materials of the limestone formation itself, which is partially converted into dolomite, we remove one source of embarrassment, whilst the other difficulties of the problem are at least in no degree enhanced.

Now it seems probable in the first place, that sedimentary limestones must originally have contained minute portions of all those ingredients which enter into the composition of animals and vegetables.

Henry Rose indeed has gone still further, remarking that he has reason to believe infinitesimal quantities even of the less common metals, such as copper, to be diffused throughout the mineral kingdom, wherever he has looked for them; at least by passing sulphuretted hydrogen through minerals of all descriptions that had been dissolved in acids, he obtained traces of the latter metal; and we know from the researches of Dr. Fownes and others, that minute portions of phosphoric acid exist in rocks of igneous origin no less than in sedimentary limestones, as indeed I have myself in many instances ascertained. That a certain amount of magnesia therefore should be contained in limestones of neptunian origin, is no more than might be expected from analogy, and there are in fact few that have not a certain percentage of this earth disseminated through them.

There is therefore present in the rock itself the material which might furnish a large amount of dolomite, and it seems at least as easy to derive it from this source, as from the igneous rock which lies in some cases contiguous.

Now the manner in which the magnesia originally disseminated through the whole mass is determined to particular beds, and thus has converted them into dolomites, may perhaps be rendered more conceivable by reference to an elaborate memoir of M. Durocher on the metamorphism of rocks, read to the Geological Society of France on the 1st of June 1846, and published in their Bulletin. This author places in a very clear light the fact, that molecular changes have gone on in rocks which were subjected to heat subsequently to their deposition, even without actual fusion taking place in the constituents. This indeed is illustrated by the artificial process of the cementation of iron with charcoal, where a minute portion of a body, which itself appears incapable of fusion, is made to pervade the entire substance of a solid mass of metal. May we not then suppose this same segregation of parts to take place in limestone rocks likewise? and may

not the magnesia previously disseminated through an extensive formation be determined to particular layers during the long continuance of a heat inferior to that which would be required to fuse the limestone, or to obliterate the traces of organization present in it?

If so, the existence of dolomites may be connected with the presence of an igneous rock without deriving its magnesian constituent from the latter source, and possibly the higher temperature of those portions of the limestone which lay nearest to the source of heat may, by enhancing the affinity subsisting between the carbonate of lime and carbonate of magnesia, favour the formation of dolomite in those parts more particularly.

If there be any truth in these remarks, dolomisation would be only a particular case of metamorphism, and the determination of magnesia to individual beds, or to veins intersecting certain rocks, may be analogous to the production of metallic veins by the segregation of metals disseminated in infinitesimal quantities through a rock, so as to occasion their collecting round certain centres, or arranging themselves along particular lines of fissure,—a wise provision of nature, without which the rarer metals would have remained for ever unknown to us, as their existence would have been as little recognisable to our senses in the older rocks, as they now are in modern lavas, where no such process of segregation has as yet taken place.

I may refer to Sir H. De la Beche's Geological Manual for a good summary of the facts relating to this subject.

Page 206.

On the Temple of Serapis at Puzzuoli.

My attention has been recalled to the subject alluded to in the above page of my Work by the receipt of a copy of Mr. Babbage's interesting "Observations on the Temple of Serapis at Puzzuoli near Naples, with a Supplement," privately printed, 1847.

As I have already given in my adhesion to the theory for which Mr. Babbage contends, I will merely remark, that he appears to me to have alleged strong objections to the Lagoon hypothesis which I had originally adopted, and which in the text of the present edition I stated to be even at the present time defensible. He has also ingeniously explained the manner in which, without supposing any fresh source of heat, the elevation of a tract of land might be occasioned by the expansion of the subjacent rocks, owing to the isothermal line, or zone of equal temperature, being brought to a higher level than it had previously occupied in the neighbourhood of the uplifted tract, and he has shown that this rise of level would be the natural consequence of a gradual filling-up of the bed of the sea, caused by the washing down from the contiguous continents of *detritus*, consisting of materials, which being worse conductors of heat than water, would cause the temperature to sink faster than it could be restored from below.

This hypothesis, it is true, disconnects the elevation of continents from the immediate action of volcanic forces, according to the view taken of the latter in the present Work, where they are referred to the extrication of steam and elastic vapours generated by certain chemical processes.

But it is quite conceivable, that whilst the original source of the heat may

have been volcanic, the elevation of certain tracts contiguous to the parts so heated may, as represented by Mr. Babbage, have taken place, long after the processes themselves had been interrupted or even had ceased, and hence it is perhaps not necessary to suppose volcanos to have been the immediate agents concerned in every part of the world, as for instance in Scandinavia, where slow elevation is going on at a great distance from any active volcano.

I would therefore merely enter my protest against its being imagined, that because internal heat may afford a probable explanation of this one phænomenon, it is to be viewed as in itself capable of solving every other, seeing that it fails even in accounting for paroxysmal elevations, being applicable solely to slow and gradual movements, and that it leaves out of sight altogether the various chemical phænomena which have been brought so prominently forward in the present Treatise.

Mr. Babbage suggests in his Supplement, that the crater-shaped appearances presented by the moon's disk may as probably be referred to coral reefs or lagoon islands as to volcanos, and undoubtedly the apparent absence of water and of an atmosphere creates quite as great a difficulty in the way of the latter hypothesis as of the former, for we are at a loss to conceive volcanic action being called forth without the extrication of steam and elastic gases, so that in either case we must assume both air and water to have existed when the reef or the volcano was in the act of forming, and in either are met with the difficulty of accounting for their absence at present.

Page 230.

Height of the Cone of Vesuvius.

Mr. Pentland has favoured me with the following measurements of the height of the cone of Vesuvius taken at different periods between the 20th of November 1845, and the 16th of August 1847, by Professor Arnaute of the Royal Engineers of Naples, and communicated by him to M. Arago.

They may serve to show the progressive increase of height which the mountain was obtaining up to the time at which the Report terminates.

20th of November 1845	1181·7 metres.
27th of February 1846	1193·9
31st of March 1846	1196·2
5th of July 1846	1219·5
16th of January 1847	1222·3
29th of March 1847	1236·8
16th of August 1847	1240·1

showing an increase of height within the last year and a half equal to 58·4 metres, or about 193 feet.

Page 313.

Professor Bunsen on Iceland.

Since the preceding pages went through the press, I have received from Professor Bunsen of Marburg two pamphlets relating to the journey in Iceland which he undertook in 1846, at the desire and with the assistance of his Majesty the King of Denmark.

The first of these pamphlets is in the shape of a letter addressed to Berzelius; the second is a memoir which was originally published in Liebig's *Annalen*, entitled "On the Pseudo-volcanic Phænomena of Iceland;" and although both the one and the other appear to be preliminary to that more full statement of his views which may be expected from him, so soon as he has brought to a close the investigations connected with the subject of his mission which he is now pursuing in his laboratory, they may be recommended to geologists as well-worthy their attentive perusal. On many points upon which he has entered I am glad to be able to cite him as an authority in my favour—as for example with reference to the abundant extrication of sulphuretted hydrogen and sulphurous acid gases from the volcanos as well as from the thermal springs of the island—the impossibility of supposing the former to be owing to the decomposition of sulphuric acid by organic matter—the exclusive derivation from the decomposition of these gases of the sulphur deposited—and the frequent disengagement both of sal-ammoniac and of nitrogen gases during all the phases of volcanic action.

On one question indeed there is a *real*, and on another an *apparent* discrepancy between our respective views.

The sal-ammoniac of the Iceland volcanos Professor Bunsen supposes to be derived, not from the interior of the earth, but from the action of the heated materials ejected, upon vegetable substances with which it may have come into contact upon the earth's surface. This is a real point of difference; but as the question has been already discussed in the course of this work, I will not here pause to consider it.

With respect however to the source of the nitrogen, which Bunsen supposes to have been carried along with the atmospheric water which finds its way down to the entrails of the volcano, my views and his do not essentially differ, although they may at first sight appear to do so.

It is indeed of no importance, whether we derive the nitrogen from atmospheric air which may reach the interior of the earth, or from the water impregnated with this element which reaches the same destination. In both these ways probably atmospheric air is conveyed to the *focus* of the volcanic action; but on either supposition we have equally to explain the cause of the abstraction of that amount of oxygen which must have entered into its composition.

Indeed, as the proportion of oxygen is greater in rain-water than it is in the atmosphere, the one being thirty-two, the other only twenty-one per cent.—by a wise provision of nature intended apparently to favour the processes of internal oxygenation—the necessity of resorting to some theory which will enable us to account for the nitrogen returning almost pure to the surface is even greater in the one case than in the other.

Passing over these theoretical differences, I will briefly notice a few other points in which Professor Bunsen appears to have thrown important light upon the phænomena of volcanos.

The whole of Iceland he regards as a table-land, possessing an undulatory surface, and sinking gradually on all sides towards the coast. It constitutes in the centre of the island a perfect desert, there being a tract of no less than forty leagues continuously, which is utterly destitute of any

shrub or green thing which could serve as food either for man or beast, and over which therefore the traveller is compelled to hurry without pausing on his road.

The whole is bestrewed not only with masses ejected from the various volcanos, but also with boulders that cannot be attributed to such a source.

They indicate in the opinion of many that the whole surface of the island was once covered with snow and glaciers,—a striking evidence, as it should seem, in confirmation of the *glacier period* supposed by Agassiz and others to have existed through the northern hemisphere.

At present perpetual snow is confined to the Jokulls, which tower considerably above the table-land just spoken of, and constitute the principal active vents of the island.

In allusion to the discovery of Ehrenberg as to infusoria being found in the ashes of the volcano, he points out, that the peaty and marshy land common in the lower parts of Iceland contains abundance of these animalcules, and that the high winds that prevail may have been the means of carrying to the region of the volcanos portions of the soil, which, with the infusoria in question, would become mixed with the volcanic products, and thus may have given rise to the mistake.

But the greater and more novel part of his remarks has reference to the action of thermal waters in modifying the structure of various volcanic products.

None of the volcanic rocks of the island are capable of resisting the decomposing influence of hot water, which, whether it comes into contact with that peculiar kind of tuff called Palagonite, of which a brief mention has already been made, p. 313—with the clinkstone and trachyte—with the older trap which has been ejected through the clinkstone—with the basaltic eruptions subsequent to the clinkstone—or lastly, with the newest lavas,—always occasions a decomposition, and gives rise to the numerous secondary products seen so abundantly in the craters of Hecla and Krabla, and in the environs of the Geysers and other thermal springs.

The siliceous products formed under the influence of warm water divide themselves into acid and basic silicates. The former become dissolved in the water, from which they are again deposited in the form of siliceous sintors, &c.; the latter form beds of clay insoluble in water, and consequently deposited as such round the spots.

The gases that accompany the steam contribute also to form new products.

When sulphuretted hydrogen predominates, iron pyrites is generated in abundance; when sulphurous acid prevails, alum, gypsum and similar minerals result.

The careful study of the action of those fumaroles which are so common throughout this island, carries us back to an examination of the theatre of that great volcanic catastrophe, which forced the trap through the tuff and clinkstone, and spread it over the surface of these rocks in extensive beds.

When dykes of clinkstone or of the older trap traverse the tuff, the latter for several feet from it shows signs of fusion, and is converted into a sort of obsidian or pitchstone; but when we observe beds of trap in contact with the tuff, scarcely any alteration in it can be traced. On more

narrowly examining the tuff however, we find as the predominant mass a very easily fusible silicate containing water, which therefore has retained its original character even to its aqueous constitution, although in immediate contact with melted trap.

Still more extraordinary appear, on further examination, the innumerable cells of the amygdaloid alternating with the tuff and trap, which are covered, and sometimes filled, with calc spar, zeolites, and other silicates charged with water.

As the tuff always contains water, we need not wonder that the inferior surface of a liquid mass of lava poured over it in a horizontal bed, should be cooled down in such a manner by the vapour disengaged, as to be able to exert no action in reducing the subjacent tuff to a state of fusion; whereas the same material, when it traversed a fissure in the rock as a dyke, might convert it into pitchstone or obsidian, in consequence of having repelled the water from the surface of the rock with which it was in contact.

According to this view of the case, we ought to be able to trace the action of these fumaroles even on the oldest volcanic products of the island, and this is found to be the case, for the amygdaloids, so rich in hydrous silicates, which alternate with the tuff and trap, afford evidences of depositions similar to those from the thermal springs at the present day.

We perceive proofs of a metamorphosis of the original stone taking place on the lines of contact between the beds of trap and tuff. Consisting, in the main, of a ferruginous or siliceous clay, they pass through numerous changes into the unaltered beds of the two rocks which bound them. Iron pyrites, chalcedony and opal, the characteristic accompaniments of the fumaroles, scarcely ever are wanting, and in short everything leads to the conclusion that this remarkable alternation of neptunian and plutonic formations is to be ascribed to the action of vapours consequent upon the volcanic eruption, that the original rock was by their influence converted into soluble and insoluble silicates, and that in this manner the amygdaloids were produced. Thus might the plastic clay generated be filled, through the vapours and gases emitted, with innumerable cells, in which we should find those products of the crystallization of the soluble silicates which pervade the clay as complementary constituents of the original material.

The abundance of infusoria met with in this tuff may be explained by the infiltration through the rock of steam, which would be favourable to the growth of such animalcules. Thus the Palagonite, which, as is stated in the text, resembles pitchstone, but is in fact an hydrous silicate, having the composition of

$$\left.\begin{array}{l}\dot{Mg}^3\\ \dot{Ca}^3\\ \dot{Ka}^3\\ \dot{Na}^3\end{array}\right\}\dddot{Si}^2+2\left\{\begin{array}{c}\underline{\dddot{Fe}}\\ \underline{\dddot{Al}}\end{array}\right\}\dddot{Si}+9\underline{\dot{H}},$$

seems full of infusoria, introduced in it at the time when the material from which it was derived was experiencing the action of warm vapours.

In short, a careful study of the action of steam and hot water, which has here been briefly alluded to, is calculated to throw much light on the production of many rocks and minerals that occur in the volcanic formations of all ages and countries.

Professor Bunsen has brought away with him, in hermetically-sealed flasks, more than a hundred samples of the gases evolved from the volcanos and thermal waters of Iceland, so that we may expect much accurate information with respect to the aëriform products of internal chemical action from this quarter.

Page 360.

On the Period of the Formation of the Dead Sea.

In Dr. John Wilson's "Lands of the Bible" just published, a different view is taken of the formation of the Dead Sea, than the one I have ventured upon in the text. This author remarks, that if the destruction of the cities alluded to was accompanied with a sinking of the entire valley to a depth of 1312 feet below its former level, which Lieut. Symonds' recent admeasurements appear to have ascertained to be the real amount of the depression, the whole of the lands of Canaan, Moab, Ammon, and the Desert must have been convulsed, and their inhabitants destroyed. But Lot, we are told, escaped to Zoar, a city quite proximate to Sodom, and was safe there; whilst Abraham, living in the plains of Mamre, near Hebron, had practical cognizance of the threatened vengeance of God only by "beholding the smoke of the country going up like the smoke of a furnace."

Hence Dr. Wilson concludes that the valley of the Jordan, together with the Wadi Arabah, which extends southwards from the Dead Sea to the Gulf of Akaba, is a fissure made by volcanic and basaltic eruptions, *long before the race of man appeared upon the globe.*

This supposition of Dr. Wilson's however is open, as it appears to me, to more serious difficulties than those he has advanced against my hypothesis. From the moment the sinking of the valley took place, all outlet for the waters of the Jordan must have been rendered impossible. They must therefore have gone on accumulating until the surface of the resulting lake was considerable enough to carry off by evaporation as much water as entered it from above—in other words, the expanse of waters could not have been smaller than at present.

But we are distinctly told, that the lake or sea was formed subsequently to the event in question, and that cities or towns existed in parts now coverèd with its waters. I adhere therefore to my own interpretation of the Scripture narrative, as encumbered at least with less formidable difficulties than that which Dr. Wilson has proposed.

Page 364.

On Volcanic Appearances in the Neighbourhood of the Red Sea.

The Ichthyophagi of the environs of Ptolemais, in the Thebaid, preserved in the time of Agatharcides the remembrance of an earthquake, during which the sea was left dry. (See Diod. Siculus, lib. iii. cap. i.)

That the following phænomena also, the knowledge of which I owe to

my friend Mr. Gray, of University College, Oxford, is connected with anything volcanic, may be uncertain; but as it is curious in itself, I shall insert his account of it, which was extracted from the newspaper called "L'Ermite du Mont Liban," published by M. Regnault, French Consul at Tripoli in Syria, and is as follows:—

No. 16, September 1820.—"M. François George Gray, voyageur Anglais, qui a visité l'Égypte et l'Arabie Pétrée, a bien voulu nous faire part, dans son passage au Mont Liban, d'un phénomène qu'il a observé avec la plus grande surprise dans un endroit appellé 'Nakous,' c'est à dire 'cloche,' à trois lieues de Tor sur la Mer Rouge. Cet endroit recouvert de sable, environné de rochers bas en forme d'amphithéâtre, offre une pente rapide vers la mer dont il est éloigné d'un demi mille, et peut avoir trois cents pieds de hauteur sur quatre-vingts de largeur. On lui a donné le nom de Cloche, parcequ'il rend des sons, non comme faisait autrefois la statue de Memnon, au lever du soleil, mais à toute heure du jour et de la nuit et dans toutes les saisons. La première fois qu'y alla M. Gray, il entendit au bout d'un quart d'heure un son doux et continu sous ses pieds,—son, qui en augmentant ressembla à celui d'une cloche qu'on frappe, et qui devient si fort en cinq minutes, qu'il fit détacher du sable, et effraya les chamaux jusqu'à les mettre en fureur.

"M. Gray, curieux de découvrir la cause de ce phénomène, dont aucun voyageur n'a parlé, retourna au même endroit le lendemain, et resta une heure à attendre le son, qui vient en effet, mais beaucoup moins fort. Comme le ciel était serein, l'air calme, il reconnut, qu'on ne pouvait attribuer ce son à l'introduction de l'air extérieur; d'ailleurs il n'avait point remarqué de fente, par où il put pénétrer. Les Arabes du désert, dont il voulut connoitre l'opinion, l'assurèrent, qu'il y avait sous terre un couvent de moines miraculeusement entretenue, et que le son, que l'on entendait, n'était autre que celui de leur cloche. Des personnes moins portés pour les miracles, pourraient conjecturer, qu'il provient d'accidens volcaniques, à cause des eaux thermales qu'on trouve sur cette côte, notamment celles bien connues d'Hammam Pharaoun (des Bains de Pharaon)."

Mr. Gray, in a letter to me, observes:—"The *camels* are an addition of M. Regnault's, as I had none with me; but I recollect repeating to him what the people of Tor told me respecting the effect of the sound upon these animals, and hence, I suppose, arose this little amplification. I beg leave to direct your attention particularly to the sound which appeared to me so extraordinary;—it *did* commence, as M. Regnault says, in a low continuous murmur, and then changed into *pulsations* as it became louder."

Seetzen (in Zach's Ephemerides, October 1812) gives a similar account of this place. It is worth inquiring, whether the noise may not proceed from the same cause as that of the Statue of Memnon, which is supposed to have stood on a sandstone rock. (See Keferstein, Beiträge zur Geschichte und Kenntniss des Basaltes, 1te Theil.) It is probable that the sound in that case proceeded, not from the statue itself, but from the ground on which it was erected.

The French naturalists who accompanied Buonaparte heard similar noises proceeding from the Temple of Carnac.

Page 377.

On the Typhon or Typhœus of the Greeks.

As the fables of Grecian Mythology generally appear to have had some foundation in fact, it seems probable that those respecting Typhon or Typhœus, reported by Hesiod and others, may afford us a clue with respect to the existence of volcanic phænomena in countries at present of difficult access.

It is evident, I think, that the fable originally came from Egypt, where, as Dr. Pritchard observes, "Typhon stood opposed to Osiris, just as Ahriman does to Orsmuzd in the religion of Zoroaster. The chief difference between the two schemes seems to consist in this circumstance, that the Egyptian fable is more entirely founded on physical principles. In the Persian doctrine Ahriman was not simply a personification of natural evil, his attributes comprehend also moral evil; but as we have seen that Osiris was physical good, or the productive or generative power, so Typhon seems to have represented all the destructive causes in nature*."

It is true that the Typhon or Typhœus of the Grecian Mythology must, as Jablonski has observed, be distinguished from the Egyptian Dæmon of the same name; but as the former people seem to have derived their mythology from the latter, it will hardly be denied that the original source of their notions respecting this evil genius, however they may have been afterwards modified, is to be sought for in Egypt.

The chief difference indeed between the two consisted in the more abstract sense in which the fable was understood by the Egyptians than by the Greeks; the former regarding, as we have seen, the Typhon as a general personification and cause of physical evil; the latter confining it to certain particular objects of terror and aversion, such as earthquakes, volcanos and whirlwinds.

It would perhaps not be difficult to explain why *these*, rather than other natural phænomena, were singled out as being immediately derived from the influence of the Dæmon.

In a climate like that of Egypt, the greatest physical evils that were to be apprehended would arise from the extreme heat, the absence of humidity, the suspension of the usual overflow of the Nile, the stifling winds of the Desert, &c. &c.

Hence Plutarch (de Iside, p. 353) considers Typhon to be *παν το αυχμηρον και πυρωδες και ζηραντικον όλως, και πολεμιον τη ὑγροτητι*, and remarks that some regarded him as synonymous with the Sun, though this was not the *orthodox* opinion.

Now it was natural that the populace, viewing the fable in a less abstract sense than the priests, should consider the Dæmon solely in this latter light, and that the Greek colonists, who probably were drawn from that class of society, should bring away with them the superstitions of the country from which they came, whilst they lost sight of the principles on which they were founded.

The considering Typhon the particular cause of earthquakes and vol-

* Pritchard's Analysis of Egyptian Mythology: London, 1819, p. 79.

canos may have happened in two ways:—1st, from the fiery nature and origin of these phænomena; and 2ndly, from the general opinion entertained by the ancients that they were caused by winds pent up within the bowels of the earth *.

This is the idea expressed by Aristotle, Meteor. lib. ii., Cornelius Severus in his interesting and philosophical poem on Etna, and various other writers; and the Egyptian word *Bebin*, which answers to Typhon, signifies, according to Jablonski, *something pent up*, or an *underground cavern*.

This opinion was indeed suggested, not only by the phænomena themselves, which seem to indicate the action of elastic vapours struggling to escape, but likewise by the simultaneous occurrence of hurricanes with earthquakes and volcanos.

Thus in the eruption in the island of Sumbawa, near Java, the greatest damage was done, not by the volcano itself, but by the whirlwind that accompanied it †.

That Typhon was considered in an especial manner the cause of whirlwinds (originally indeed of the scorching wind of the Desert, but afterwards among the Greeks of all pernicious blasts ‡), is evident from the lines in Hesiod's Theogenia, quoted at length at the bottom of page 403.

It may be remarked, that the Egyptian, as well as the Grecian Mythology, agree in a remarkable manner with the systems of certain modern geologists, who imagine volcanos to be the expiring efforts of that force, to the more general action of which they ascribe the elevation of mountains, and the formation of the older strata. They also correspond with the opinion, that volcanos at present are less extensively distributed than they were at former periods of the earth, and consequently that their influence may be inferred to be on the decline.

Conformably with this, the Egyptians imagined that Mercury has cut the sinews of Typhon, and that he has since lost the power that originally belonged to him, having sunk from his "high estate" as the general worker of evil, to that of the framer of earthquakes, thunder, and hurricanes §.

So also Hesiod, after describing the manner in which Jupiter overcame the Titans and other monsters, which Mother Earth had successively produced to contend with him, says, that Typhœus, the author of whirlwinds and earthquakes, was the youngest of her children.

It may be remarked, that this poet notices the Typhon in an earlier part of the same poem, and therefore appears to distinguish him from Typhœus; but it will hardly be supposed that the attributes of the two dæmons, both resembling each other in name, and derived in all probability from the same Egyptian source, would be very accurately distinguished.

Let us therefore, without attending to this distinction, proceed to con-

* See note to page 403. It is alleged also by Tilesius, who accompanied Krusenstern, that the cause of the Typhon of the Chinese Sea is to be sought for in the bowels of the earth, and depends on agitations at the bottom of the sea.—Edinb. Journ. of Science, vol. ix. p. 204.

† See page 402.

‡ Hence locusts are called "the children of Typhon."

§ See Plutarch de Iside et Osiride.

sider how far the descriptions given of either, or both of these monsters, correspond with the hypothesis as to their being more especially intended as personifications of volcanic action.

The account given by Apollodorus is perhaps the most circumstantial, and agrees very well with that of Hesiod, the earliest writer, except Homer, by whom Typhon or Typhœus is mentioned.

This mythologist describes him as surpassing in size and force all the children of Earth; he was taller than all the mountains, his head often touched the stars; his arms stretched, the one to the setting, the other to the rising of the sun. The serpents, which were twisted round his thighs, rose to his head, and sent forth a horrible hissing; fire gleamed from his eyes; he hurled stones to heaven with a loud and hollow noise (*μετα συριγμων ὁμου και βοης*); surges of fire boiled up from his mouth (*πολλη εκ του στοματος εξεβρασε ζαλη*).

How well this corresponds both with the structure and phænomena of a volcanic mountain, I consider it needless to point out, and shall therefore proceed to mention the spots in which the scene of the monster's adventures are laid; for, as in the many instances where these have been explored their nature is found to be volcanic, there seems a reasonable presumption that the same may be the condition of such as have not been examined.

Now Apollodorus mentions that Typhon was born in Cilicia, where we know of the existence of an extensive volcanic district called the Catacecaumene. When pursued by Jupiter, he fled to the neighbourhood of Mount Casius on the borders of the Lake Serbonis, near the Pelusian branch of the Nile. What the nature of this lake and of the mountain near it may be, I have not been able to ascertain. Jablonski however says, that the lake has a great affinity to the Dead Sea, which seems to owe its existence to a volcanic eruption. Maillet, in his Description de l'Égypte, p. 129, says, that the Egyptians got their bitumen for embalming from thence, and not, as is generally supposed, from the Dead Sea. The word (Ser) in Coptic, it is said, means *to sprinkle*, and (Bon) *fœtid*; and Manetho says, that the lake in his time emitted hot exhalations.

One of the cities, called Typhonia, formerly existed there, and the Egyptians called the lake *Τυφωνος εκπνοαι*. (Plutarch, Vit. Ant. p. 917.)

It must however be confessed, that the pestilential vapours which arose from the water may alone have caused it to be considered the abode of Typhon, and that with regard to the particular passage referred to commentators are not agreed, for Heyne proposes to substitute, for Casius, Caucasus, where there was a rock which went by the name of Typhonian. It is indeed not improbable that the latter may be the true reading, as it appears that volcanos actually exist there*; or if we suppose that the mountain alluded to was Demavend, which stands near the famous Caucasiæ portæ, and therefore may perhaps have been viewed by the ancients as belonging to that chain, the Typhœus of the Greeks would then be the Zohag of the Zend-avesta, confined, according to the Persian mythology, under their volcano, as the Grecian monster was under Etna or Cumæ†.

The other places mentioned by Apollodorus as the scene of these adventures are, Mount Hæmus in Thrace, so called from his blood which was

* See p. 367, *et seq.* † See p. 377.

there spilt; the peninsula of Pallene; and Mount Etna; but others have mentioned Lydia, Phrygia and Bœotia, as the spots where he was finally vanquished. (See Tzetzes, Scholia in Lycophron.)

Homer, as I have already stated, makes the Arimæan mountains (which perhaps may have been those near the Dead Sea*) the bed of Typhœus; and it is worth remarking, that neither that poet nor Hesiod alludes to Mount Etna as the abode of the monster, as Pindar and other later writers have done. This may be considered as an additional proof that this volcano was not in action about the period at which they lived. Now we have abundant proofs of volcanic action in most parts of Asia Minor, and particularly in the provinces of Lydia, Phrygia and Cilicia†; such are the extinct volcanos near Smyrna and Scandaroon, the Plutonium, or Corycian Cave, noticed by Strabo and re-discovered by Chandler, and the destructive earthquakes so common throughout that country; we have accounts likewise of a mud-eruption in the Lelantic fields near Chalcis in Eubœa‡, which, if it was not itself of a volcanic nature, indicates, like the phænomena of Macaluba in Sicily, the accumulation of materials brought together by previous volcanic agency. It remains to be seen whether the same holds good with regard to the other spots alluded to, viz. the Lake Serbonis, the peninsula of Pallene, and Mount Hæmus in Thrace. I believe the Ceraunian mountains are also mentioned as the seat of Typhon, but this has arisen from a lambent flame which still plays on the summit of some of them, arising from the escape of an inflammable gas, as on the top of the Apennines between Florence and Bologna§. The same seems to be the case with regard to the δικορυφον σελας mentioned as occurring on the top of Parnassus.

I cannot close this note without pointing out the curious coincidence of names between those places in Asia and in Europe, noticed either as the abode of Typhon, or as the site of igneous phænomena.

EUROPE.	ASIA.
Nysa, one of the peaks on Mount Parnassus noted for the flame that emanated from its summit.	Nysa in Cilicia, the spot where Typhœus was struck with lightning.
Corycian Cave, on Mount Parnassus.	Corycian Cave in Cilicia, where Jupiter was confined when vanquished by the monster. It was noted for its Plutonium, or a Grotto del Cane like that near Naples.
Hæmus in Thrace, where the blood of Typhon was spilt by Jupiter.	Hæmus near the Lake Serbonis in Egypt, where were the exhalations or breathing-holes of Typhon, Τυφωνος εκπνοαι.

* See p. 345.
† See p. 340, *et seq.*
‡ See p. 330.
§ See p. 331.

EUROPE.

Inarime, now called Ischia, under which island Typhœus is said by Virgil to be oppressed. Its other name was *Pithecusa*, from the Apes which abounded there (πιθηκοι), and the name Inarime was probably derived from the same cause, as we are told that *Arimi* in the Etruscan language signified *Apes*.

ASIA.

The Arimæan mountains, mentioned by Homer as the bed of Typhon, the Τα Αριμα, are placed by some in Cilicia, by others in Syria. There is no doubt however as to the existence in the former country of mountains that went by that name, and though they probably derived it from being peopled by Syrians, the descendants of Aram, yet it is a singular coincidence, that *Apes* were sacrificed in a temple of Diana that stood in this country. (See Strabo.)

Page 412.

Nicobar Islands.

It would appear from a geographical sketch of the Nicobar Islands just published at Copenhagen by Dr. Rink, the naturalist to the Danish Exploring ship, the Galatea, that the volcanic band traced from Sumatra to Chittagong does not include this group, which consists of coral-reefs, although the island Bambuka, from its form, has all the appearance of being a crater.

Page 436.

On the Geological Structure of Kerguelen's Land.

Since this work went to press, the publication of Sir James Ross's Voyage of Discovery has made known to us more of the physical structure of Kerguelen's Island than had been previously explored.

It appears by the report given by Mr. M'Cormick, the surgeon of the Erebus, that the northern extremity of the island visited by the expedition was entirely of volcanic origin, composed of trap rocks disposed in a series of nearly horizontal terraces, consisting of prismatic basalt passing into greenstone, and of various modifications of amygdaloid and porphyry, often intersected by dykes.

Several conical hills with crater-shaped summits appear to have been volcanic vents. The most remarkable feature is the occurrence of fossil wood and coal imbedded in the igneous rocks. The wood is often much silicified, and of large size. The coal is slaty, of a brownish-black colour, and a fracture like wood-coal. One bed in Cumberland Bay (north-west coast) is two feet thick, with a slaty fracture and dull brownish-black colour, covered over by amygdaloidal greenstone.

The point most worthy of remark is the former luxuriant growth of timber-trees in this inhospitable climate, where there is now the utmost paucity of vegetation, and not even a shrub is to be seen.

Page 513.

Cacciatore's Seismometer.

It may not be amiss to append a drawing of a Seismometer of very simple construction, invented by Professor Cacciatore of Palermo, which, according to Frederic Hoffman, has been much used in registering the direction, and even in some degree the intensity, of the earthquakes that occur in Sicily.

The instrument consists of a flat circular dish of wood with a very smooth bottom, and about ten inches in diameter, surrounded with a rim in which eight holes are bored at equal distances apart.

Outside of the rim is a kind of circular projection somewhat curved, and with eight grooves corresponding with the eight holes bored in the rim. Underneath the lower extremity of each groove a little cup is placed, and the whole rests upon a pedestal in such a way as only to be moved by an earthquake affecting the locality.

The upper part of the dish is filled with mercury up to the level of the holes bored in the rim surrounding its margin; so that in whatever direction the elevatory shock occurs, the mercury will flow out into the cup standing opposite to it.

The following is a sketch of the instrument:—

Page 634.

On Paroxysmal Actions.

In addition to Mr. Hopkins, Sir Roderick Murchison, and other professed geologists, I may cite the authority of Dr. Whewell in favour of the doctrine of paroxysmal or sudden elevation as applied to the explanation of the great Northern Drift.

The transfer of so large a body of matter over so vast an area he regards as an irresistible evidence of paroxysmal action.

"As no gradual or minute action could move the masses in question through a yard of space, no accumulation of such action, through any amount of time, could distribute the masses through the great distances which the northern drift has traversed, and spread them over the vast spaces which that formation occupies. The distribution of the northern drift belongs to a period when other causes operated than those which are now in action."—Quarterly Journ. of the Geol. Society for August 1847.

Page 652.

On the Origin of the Carbonic Acid discharged from Volcanos.

In his recently published work, entitled 'Lehrbuch der Chemischen und Physikalischen Geologie,' Prof. Bischof has entered at length into the subject of the evolution of carbonic acid from the interior of the earth. He is entirely opposed to the idea of its being derived from the combustion of carbonaceous matters in the interior of the earth, or from the products of animal or vegetable decay. He regards it, as I myself have done, due rather to the action of silica upon earthy and alkaline carbonates, by which carbonic acid is disengaged and silicates are produced. Nevertheless he does not suppose the carbonic acid to be immediately discharged from the lava, but rather to be entangled within its tough and viscous substance so long as the latter continues in a semifluid condition, being subsequently emitted as each part becomes solid and begins to crack. This view is entirely conformable to my own observations on the lava of Vesuvius in 1834 (see page 229), with regard to the evolution of muriatic acid, muriate of ammonia and steam from the cracks and crevices of the semi-molten mass, and is perhaps rendered more conceivable from the fact, that carburetted hydrogen gas in a condensed state is found to be confined within minute cells in the salt of Wieliczka, from which it escapes with a succession of little reports, when the salt is immersed in water, as fast as the solution of the latter is effected. It may moreover explain the evolution of carbonic acid taking place, not at the time of a volcanic eruption, but at one subsequent to it, when the lava begins to cool, and the proportion of lime commonly present in lava would, if it had previously existed as a carbonate, have supplied carbonic acid enough to account for the *mofettes* that occur in their respective districts.

Page 654.

Reply to Professor Bischof's Further Reasons against the Chemical Theory of Volcanos.

[Prof. Bischof's paper may be seen entire in the Edinburgh New Philosophical Journal, vol. xxx.]

First Objection.—According to the chemical theory, the intense heat of lavas would arise from chemical processes supposed to be taking place. Now no supposable amount of chemical action could engender so much heat as is here assumed.

Reply.—If volcanic action arise from chemical processes, it follows necessarily that the latter must be commensurate to the extent to which the former prevails; and if it consist in the oxidation of the bases of those bodies which are presented to us as the products of the operations which take place, there would surely be no want of materials for producing a chemical action capable of bringing the lavas, &c. ejected into a state of fusion, for the heat must always bear a constant ratio to the amount of lava generated, or, in other words, to the weight of inflammable matter oxidated. The whole objection therefore resolves into the former one so often before discussed, viz. the probability of such chemical action having taken place.

Second Objection.—Supposing caverns to exist near or about the *focus* of a volcano, and these to be filled with air, the communication between such hollows and the atmosphere must be stopped up so soon as lava came to be emitted. Hence the action would be discontinued for want of air to carry it on.

Reply.—I cannot figure to myself a cavern in the interior of the earth so hermetically sealed as to be impermeable to air when a partial vacuum took place within it. Even if the lava were to seal the mouth of the crater, and thus put a stop to the emission of solid or liquid matter, it could hardly spread itself over the whole internal surface of the cavern so as to close all its fissures and bar the ingress of air; nor if it did, could it prevent new ones from being formed, so soon as the rock began to contract.

Now admitting this communication with the external air to exist, it is surely a waste of time to calculate the size of a cavern which could supply oxygen enough for any supposed amount of lava, since whatever air was lost by oxidation in and about the cavern itself, would be immediately supplied by the atmosphere in connexion with it.

Third Objection.—Volcanic actions are deep-seated, but the chemical processes assumed are of such a nature as to be developed only near the surface.

Reply.—No reason is assigned, why chemical actions, excited by the access of air and of water to metallic bodies of a highly combustible nature, may not take place at any depth whatsoever.

Fourth Objection.—If these chemical actions were supported by atmospheric air, vast volumes of nitrogen must be evolved in consequence. Now the amount of nitrogen observed is after all but inconsiderable.

Reply.—This objection implies a more thorough acquaintance with volcanic phænomena than we are as yet entitled to assume.

How do we know what amount of nitrogen may be evolved during the more active periods of volcanic action?

How can we be justified, *à priori*, in laying down what proportion of the effect produced is due to atmospheric air, and how much to water?

The more philosophical mode of treating the subject seems to me to be, to content ourselves with endeavouring to account for the products which we have hitherto succeeded in detecting. Amongst these are nitrogen, sulphurous acid and sulphuretted hydrogen. The two former clearly imply atmospheric air, the latter water, to have been present.

The amount of all the three collectively taken, Bischof contends to be inadequate to the effects of which I regard them as the results; but can he, especially after Pilla's observations, assure himself that the quantity of one or of all may not be greater than has yet been determined? and can he account even for the amount ascertained to be emitted without having recourse to some such hypothesis as the one I have proposed?

Even of nitrogen, the quantity emitted during languid volcanic action seems greater than can be explained by any decomposition of organic matter, bating other objections to such a solution—witness the thermal waters of Bath, where the amount is no less than 250 cubic feet in twenty-four hours—whilst of sulphuretted hydrogen the quantity disengaged must exceed what we can account for by the decomposition of sulphates, if we sup-

pose such beds of sulphur as those in Sicily to have resulted from its decomposition,—not to allude to the fact, that the sulphates themselves can best be attributed to the sulphuric acid generated owing to a previous decomposition of sulphuretted hydrogen.

How difficult too is it to suppose such an amount of organic matter, as must be assumed in order to explain, according to Bischof's theory, the evolution of nitrogen no less than of sulphuretted hydrogen, existing for so many ages in the very focus of volcanic heat! These however are points that have been before sufficiently insisted upon.

Fifth Objection.—If lava were formed by the union of the metallic bases assumed with oxygen derived from water, the quantity of the latter decomposed would be immense, and the quantity of hydrogen emitted equally so. Now as this hydrogen comes to the surface in union with sulphur, the amount of the latter concerned in the process must have been greater than can well be conceived. Moreover sulphur cannot be united to hydrogen by direct chemical means, and lastly, according to this hypothesis, the disengagement of sulphuretted hydrogen ought to precede the emission of lava, instead of following it, as is more commonly the case.

Reply.—The first part of the objection has been already met. It is not necessary to suppose that the whole of the sulphur finds its way to the surface, since sulphurous acid and sulphuretted hydrogen might be formed at the same time, and thus, by the mutual action of these bodies one upon the other, water might be reproduced and sulphur deposited.

With regard to the doubt expressed as to the possibility of an union of sulphur with hydrogen taking place, is not the latter, I would ask, at the instant of its disengagement, in precisely the same nascent condition, as when sulphuric acid liberates it from a moistened metallic sulphuret? Is it not even possible that the alkaline or earthy metalloids may exist as sulphurets in the interior of the earth? With regard to the last point, as to the order of succession in which the phænomena take place, there seems no necessity for supposing the lava emitted to be exactly the same as that which has just been generated, nor do I know but that sulphuretted hydrogen may exist among the gaseous products by means of which the stones and ashes which precede an eruption are ejected from the crater.

But, after all, I am quite willing to admit that difficulties, to which none but conjectural answers can be returned, may be started to this as well as to every other hypothesis. If what we propose be an approximation to the truth, it is as much as can be expected, and the only fair way of estimating its claims, is to compare the difficulties that beset it with those which may be alleged against any other rival explanation.

Now the presence of an unlimited supply of organic matter for ages in contact with substances undergoing intense heat—the evolution of so much sulphuretted hydrogen without decomposition of water—the constant disengagement of nitrogen without any mode of accounting for the simultaneous abstraction of oxygen—the production of heat being promoted, instead of being checked, by the access of water—and other particulars which will easily occur to my readers—undoubtedly require an explanation before we can consent to espouse the opposite theory.

Sixth Objection.—There could not be chlorine enough evolved to unite

with so enormous a quantity of hydrogen as that which my hypothesis assumes; nor could the latter unite with oxygen, without occasioning such a consumption of that element as would render the air in the immediate neighbourhood of the volcano unrespirable.

Reply.—The muriatic acid evolved is a sufficient index of the amount of chlorine which has combined with hydrogen. Estimated by this standard, its volume must be considerable, as may be understood from the copious evolution of muriatic acid during volcanic eruptions, but no one has ever contended that it was commensurate with the amount of hydrogen evolved. The remainder of the latter either comes to the surface as sulphuretted hydrogen, or unites with oxygen derived both from the air which enters the interior of the earth, and from the sulphurous acid at the same time generated, thus contributing to reproduce an equivalent amount of water.

Seventh Objection.—Lava, when freshly emitted, and in a liquid or ignited state, contains no traces of the bases of the earths and alkalies, or even of metallic iron.

Reply.—With all due deference to the excellent chemists who have originated this objection, I am at a loss to conceive how potassium, sodium, calcium, &c., could be expected to occur in the midst of a lava-current. That which I examined in 1834 was evolving at the very time water and muriatic acid. How could such combustibles exist in contact with these oxidizing agents? Even metallic iron, under such circumstances, could scarcely be found; but, on the other hand, the presence in volcanic products of this same metal in the state of magnetic iron instead of a peroxide, conveys to my mind a strong presumption, that hydrogen has exerted that deoxidizing influence which Sir Humphry Davy and Professor Bischof demand as indications of its presence.

In reply to Dr. Bischof's concluding remarks, as to whether the defenders of the chemical theory suppose granite, trachyte, basalt, porphyry, to have all resulted from the same chemical processes which they imagine to be going on in volcanos at present, I may refer to my 40th chapter both for a reply, and for the grounds on which the affirmative of this question may be supported. I would moreover ask, whether, if it be true that the gases observed to issue from a volcano during the several phases of its action, confessedly imply the existence at the present time of chemical processes of such a nature as, if carried on on a sufficiently extensive scale, would account, both for the heat of the globe, and for the various volcanic phænomena which the earth presents, it be not more philosophical to regard these processes as the main instruments of the changes brought about, than to ascribe the eruptions of the volcano to one set of causes, and the gases, &c. which accompany or rather follow after them, to another independent series of operations?

Page 658.

On the Tertiary Lavas.

M. Menard de Groye, in his account of the volcano of Beaulieu, seems to have adopted in some degree the same ideas with those expressed above, with respect to the cause of the differences between basalt and lava. They

are, he says, precisely such as we might expect, from the one being submarine, the other produced in the open air:—

"L'air de vétusté, qui se voit empreint, si l'on peut dire, sur toutes ces terrains trappéens; la destruction de tout cratère, s'il y en eut parmi eux; cette stratification, qu'on leur assigne pour ordinaire, mais que je n'ai presque jamais bien reconnue; leur alternation, observée en Saxe, dans le Vicentin, dans le Derbyshire et ailleurs, avec des couches de sable, de pierre calcaire, et ces corps hétérogènes coupées même quelquefois dans le basalt et dans la wacke; la fragilité qui se fait remarquer généralement dans les matières trappéens; leur état plus crystallin ou du moins plus grenu; la stratification très rare parmi elles; toutes ces singularités si inexplicables dans d'autres hypothèses deviennent faciles à concevoir, et à expliquer, dans celle que nous proposons."—Menard de Groye, Journ. de Physique, vol. lxxxii.

He then goes on to consider the *third class*, namely that of incomplete immersion, when a volcano is bathed in water at its base, whilst its summit is elevated above the waters, in which class he places those which I have called Tertiary volcanic rocks, such as Beaulieu, Vicentin, Meisner, &c.

But I cannot agree with this author in attributing the formation of columnar basalts to their being elevated above the waters; nor can I admit the fact to which he appeals, namely that the basalt at Beaulieu passes into greenstone in the lower part, as a proof that the former was ejected above, the latter below, the level of the then existing water. Such an idea accords indeed very well with what I have elsewhere said *with regard to the dependence of crystalline arrangement upon pressure*, but unfortunately it happens that the basalt is seen quite as frequently passing into greenstone in its upper as in its under part, as is the case in the very instance of the Meisner, to which Menard alludes.

I believe I have stated fairly the theory proposed by M. Menard de Groye, to explain the distinction between basalt and lava, and have enabled my readers to judge how far my ideas have been anticipated by this author; for although I did not read his memoir until after my treatise was composed, he has of course a fair claim to *priority*, where the opinions are the same. It will be seen however, that though Menard finds himself obliged (as I conceive every geologist will be, who examines with attention the tertiary volcanic rocks) to make a distinct class of them, yet he does not explain the cause of their differences on the same principles as myself. According to him, the differences arise from their being formed partly above, partly below the surface of water; an explanation which may indeed account for some of the differences, but does not appear to me altogether to supersede the necessity of imagining that they have been in certain instances formed under a body of water less considerable than the ocean. With respect to basalt, his views are diametrically opposite to mine, as he considers it to be so formed in consequence of the absence of water, whereas I have explained its compactness from its being produced underneath that fluid. Indeed M. Menard does not appear in any part of his memoir to allude to the difference in the state of compression produced by the presence or absence of water.

Dr. Boué, in his memoir on Germany, has also alluded to a similar

distinction (Journ. de Phys. vol. xcv.) of volcanic products, which he divides into those caused by volcanos burning in the open air, and by the same more or less submarine, or burning under water.

Under the head of those partially submarine he includes trachytes and many basalts, and this division obviously corresponds with my second class of tertiary volcanic products. The rocks included by Dr. Boué and by myself are nearly the same.

Dr. Boué has also noticed in common with myself the following distinctions between submarine and subaërial volcanos: viz. that they originate from dykes, form mountains of inferior height, and are associated with tuffs possessing a strong degree of aggregation. He also remarks the greater frequency of crystalline infiltrations, and the more decided changes effected upon the surface of the ambiguous rocks. It is satisfactory to find my observations thus confirmed, or rather anticipated, as it proves that they have not been *imagined* for the sake of propping up an hypothesis, but that the principles laid down by Sir J. Hall admit of a more extended application than appears, so far as we can collect from his writings, to have been anticipated by their author.

Page 665.

On the Oscillations of Opinion with respect to the Origin of Trap.

That I am warranted in speaking as I have done of the oscillations of opinion which have prevailed respecting the origin of basalt, will be evident from the following passage in Daubuisson's account of the basalts of Saxony, translated by Neill:—"It appears," says the celebrated chemist of Berlin*, "that naturalists are recovering by degrees from the *volcanic illusion*. It is about fifty years since a French naturalist revived the opinion concerning the volcanic origin of basalt, and he lived to see almost all Europe adopt his sentiments. Bergman, the first of the chemists who employed himself with diligence and success in examining mineral substances, and who, to an intimate acquaintance with the effects of heat, joined an extensive knowledge of mineralogy, could not bring himself to consider basalt as a product of volcanic eruptions. The Swedes adopted his view of the question. *It is scarce forty years since everybody in Germany considered basaltic mountains as ancient volcanos. Werner lifted the neptunian standard; and now, among all the German mineralogists of any reputation, I know but one (Voigt) who still retains the old doctrine.* We have already seen in how decisive a manner Klaproth has pronounced on the subject: he, of all the German chemists, has had most opportunities of observing the effects of fire on mineral substances, and he has besides studied the history of basaltic mountains with that correctness for which he is remarkable. In Ireland Mr. Kirwan was a supporter of the volcanic doctrine; but the numerous chemical experiments which he made on minerals, and other considerations, led him to a change. Dr. Mitchell, one of the very best mineralogists, Mr. Jameson, the author of the Mineralogical Travels in Scotland, and the greater part of British naturalists, consider basalt as having been produced in the humid way."

* Klaproth, Journal des Mines, No. 74.

The geologist who of all others possessed the greatest experience—Saussure, the illustrious mineralogist of the Alps—found it necessary, in the latter part of his life, greatly to limit his notions as to basalt being of volcanic origin. In speaking of the extinguished volcanos of Brisgau, he says*: "I acknowledge that, before studying the writings of Werner, I felt no hesitation; but that philosopher has taught me to doubt." Dolomieu, who was at the head of the Vulcanists, but in whom the love of truth was paramount to the spirit of party, admitted that some basalts had been produced in the humid way. He observes: "I have circumscribed the volcanic empire more than any other mineralogist, French, English, or Italian, having withdrawn from its dominion many mineral substances formerly placed under it. I hold that the basalts of Saxony, of Scotland and of Sweden, may claim neptunian origin." When treating of the basalt of Ethiopia, he adds, "I may affirm with certainty, that it is not of volcanic production†."

These opinions, whilst they afford a satisfactory proof of the progress that has been made in geology within the last thirty years, will perhaps show, that at the time alluded to, and even for some years later, it was by no means considered a superfluous task to hunt for proofs in Auvergne and elsewhere, for the purpose of placing on a surer footing the igneous origin of trap.

Page 693.

On the Existence of Iodine and Bromine in the earliest Seas.

In confirmation of the remarks made on the unchangeableness of the laws of Nature from the earliest times, I may refer to the remarkable fact pointed out in my Memoir "On the Occurrence of Iodine and Bromine in the Mineral Waters of South Britain," (Phil. Trans. 1830) namely that the earliest seas appear to have corresponded with those at present existing, even with respect to the minute proportions of the above-named principles which were present in them.

* Journal de Physique, tom. xxxvii.

† Daubuisson on Basalt, Neill's Translation, p. 163.

LIST OF

WORKS RELATING TO VOLCANOS.

[In drawing up the List of Works on Volcanos, &c., both for this and for the former Edition, I have been greatly assisted by my friend Dr. Boué, well known for his extensive travels in Transylvania, European Turkey, Germany, &c., and also for his thorough acquaintance with the literature of Geology, of which I trust the Public will one day or other reap the benefit. As the additions to the Catalogue made by this Geologist have been only communicated recently, several works that may be of importance are herein noticed, of which no mention has been made in the body of the Work.]

ON THE VOLCANOS OF FRANCE.

Guettard......... Mémoire sur quelques Montagnes de la France, qui ont été des Volcans. Mém. de l'Acad. des Sciences, 1752.
Mémoire sur la Minéralogie de l'Auvergne. Mém. de l'Acad. des Sciences, 1759.
Desmarest ...... Mémoire sur le Basalte.
Ditto. Journ. de Physique, 1779.
Ditto pour 1774, p. 705.
Faujas St. Fond. Volcans du Vivarais. Fol. 1778. This work also contains an account of the Volcanos of Forez.
Giraud Soulavie. Histoire Naturelle de la France Méridionale. 1780.
Legrand d'Aussy. Voyage en Auvergne, 1st and 2nd vol. 1788; 3rd vol. 1794.
Montlosier ...... Essai sur la Théorie des Volcans d'Auvergne. 1789. Highly interesting, and conveying upon the whole correct views, notwithstanding its old date.
Buchoz .... Sur le Cantal. 1792.
Dolomieu ...... Rapport. Journal des Mines, Ann. 5 & 6.
Description des Courses Lithologiques. Journ. de Pharm. tom. 1. p. 127.
Observations. Soc. Philom. Ann. 6. p. 73.
Sur les Volcans de l'Auvergne. Journ. de Physique, 1798, vol. 46. p. 406–418.
D'Aubuisson ... Desc. des Volcans et Basaltes d'Auvergne. Journ. de Physique, 1804, vol. 58. pp. 310, 422; vol. 59. p. 367. 1819, vol. 88. p. 432–449.
Lacoste .... Sur les Volcans de l'Auvergne. Ann. 11.
Lettres, &c. 1805.
Marzari Pencati. Orittographia del Monte Coiron. 1806.
Cocq .... Lithologie de l'Auvergne. Journal des Mines, tom. 19, 1806.
De Laizer ...... Sur le Puy Chopine. 1808.
Sol d'Auvergne. Journ. des Mines, tom. 23. p. 40.
De Laizer, Weiss, et Gillet Laumont. Sur les Laves avec parties bleues. Journ. des Mines, tom. 23.

Ramond .... Hauteurs mesurées barométriquement. Journ. des Mines, tom. 24. The same Memoir in a more complete form. Acad. des Sciences, 1813–1815. This Memoir is more than it professes to be, including, together with barometrical measurements, judicious remarks on the geology of the country.

Cordier .... Sur le Mont Mezen. Journ. des Mines, tom. 26. Journ. de Physique, vol. 69.
Sur le Brèche de Mont Dor. Tom. 4, 1819.

Buch, Von ...... Mineralogische Briefe aus Auvergne. In the 2nd vol. of his Geognostischen Beobachtungen, 1809.
Journal des Mines, tom. 13.

Vital Bertrand. Essai sur l'Histoire Naturelle du Puy. 1811.

Boué, A.......... Comparison of the Rocks of Auvergne and Scotland. Edinb. Phil. Journ. 1819.
Contact du Tufée volcanique et des Marnes au Puy Crouelle. Essai sur l'Ecosse, 1820, p. 482.

Hoff, Von ...... On the Account given by Sidonius Apollinaris of the Volcanic Mountains of France. N. Jahrb. d. B. u. H. de Moll. 1821, vol. 4. p. 183–193.

Daubeny......... Letters on Auvergne addressed to Professor Jameson. Edinb. Phil. Journ. for 1820–21. It may serve as some kind of apology for any deficiencies and inaccuracies which may be detected in these Letters, to state, that they contain the first special description of the Volcanos of France that had appeared in the English language.
Letters on Auvergne, translated into German by Professor Nöggerath, with Notes and Corrections. Bonn, 1825.

Bakewell's ...... Travels in the Tarentaise. 2 vols. 8vo. London, 1823.

Bertrand Roux. Description du Puy en Velay. 1823. An excellent account of the physical structure of that part of France.

Steininger ...... Erloschenen Vulkane in Sudfrankreich. Mainz, 1823.
Bemerkungen über die Eifel und Auvergne. 1824.

Nöggerath ...... Vorkommen von Fossiler Saügethier-resten in der Auvergne. Karsten Archiv, 1824.

Menard de la Groye. Sur Beaulieu. Journ. de Phys. vol. 82. There is also a Memoir on the same subject by Saussure, in the same Journal for the year 1787.

Marcel de Serres. Volcans d'Agde, St. Thibery et Mt. Ferrier. Journ. des Mines, 1808, vol. 24. p. 231.
Volcans éteints du midi de la France. Mém. Soc. Linn. Normandie, vol. 3. p. 161. Mém. du Muséum d'Hist. Nat. 1827. These have reference to the volcanic rocks of the Cevennes.

Chabriol et Bouillet. Essai sur les Environs d'Issoire et la Montagne de Boulade. 1827.

Bormard, De ... Basalte du Drevin Bourgogne. Ann. des Mines, 1828, vol. 4. p. 436.

Guillardot ...... Produits Volcaniques ou plutôt Basaltiques de Bédon à une lieue de Chatel sur Moselle. Précis des Travaux de la Soc. Roy. de Sc. &c. de Nancy pour 1824–28 (1829), p. 51.

Scrope............ Geology of Central France. London, 1827, 4to. Accompanied with an Atlas, containing beautiful and instructive panoramic views of the volcanic mountains in Auvergne.

Lyell and Murchison. On the Excavation of Valleys as illustrated by the volcanic rocks of Central France. In Edinb. Journal of Science for 1829, vol. 21.

Kleinschrod ... Coup d'œil géol. sur une partie de l'Auvergne. Hertha, 1829. Vol. 14. p. 3–72.

Bouillet .... Topographie Minéral du Puy de Dôme. 1829.

Lecoq et Bouillet. Coup d'œil sur la Structure géol. et min. des Monts Dors. 1831.
Itinéraire du Dépt. du Puy de Dôme. 1831.

Daubeny......... On the Diluvial Theory, and, The Formation of the Valleys in Auvergne. Edinb. New Phil. Journ. 1831.
Bouillet .... Itinéraire Minéralogique de Clermont à Aurillac, &c. 1832.
Courses de la Soc. Géol. de France depuis Clermont-Ferrand, 1833. Bull. Soc. Géol. Fr. vol. 4. p. 1–60.
Annales Scientifiques et Industrielles de l'Auvergne. Many papers.
Burat .... Description de la France Centrale. 1 vol. 8vo. 1833.
Prévost, Const. Sur les Groupes Volcaniques du Cantal et du Mont Dor. Bull. Soc. Géol. Fr. 1833, vol. 4. p. 124. (Against the theory of Craters of Elevation, and Dufrénoy and Elie de Beaumont's Views on that subject. Ann. des Mines, 1833.)
Dufrénoy et Elie de Beaumont. Mémoires pour servir à une Description Géologique de la France. 1830–38.
Explication de la Carte Géologique de la France. 1841. Vol. 1. Often referred to in the course of this volume, as advocating the theory of Elevation in its application to the volcanic rocks of Auvergne.
Boubie .... Promenade au Mont Dor. 1833.
Desgenevez...... Sur le Cantal et les Monts Dors. Mém. Soc. Géol. Fr. 1834, vol. 1. pt. 2. p. 175.
Fournet .... Sur les Révolutions qui ont modifié les Monts Dors. Ann. des Mines, 1834, vol. 5.
Pissis .... Sur le Basalte de La Roche, et les Phénomènes qui ont accompagné son apparition. Le Puy, 1835, 8vo.
Forbes, Prof. J. On the Geology of Auvergne. Edinb. Phil. Journal of Science, 1836. Advocates the Elevation theory.
Lecoq, H. ...... Sur les petits Lacs des Terrains Basaltiques de l'Auvergne. Clermont-Ferrand, 1838, 8vo.
Cordier .... Sur les Systèmes Volcaniques de l'Intérieur de la France. Bull. Soc. Géol. Fr. vol. 2. p. 401.
Pissis .... Sur l'âge et la position des Terrains Volcaniques du centre de la France. Bull. Soc. Géol. Fr. 1843, vol. 14. p. 240.
Rozet .... Sur les Roches Plutoniques de quelques parties de la Chaine qui sépare la Saone de la Loire. Bull. Soc. Géol. Fr. vol. 7. p. 120; vol. 8. p. 122. Mém. Soc. Géol. Fr. 1840, vol. 4.
Sur les Volcans de l'Auvergne, avec un App. sur les Volcans d'Italie. Mém. Soc. Géol. Fr. 1844, vol. 1. pt. 1. p. 51–162.
Leymerie ...... Ditto, vol. 7. p. 212.
Lyell .... Age of the recent Lava *Coulées* in Auvergne. Quart. Journal of the Geol. Soc. of London, 1846, vol. 2. part 2. p. 75.

GERMANY.

1. WESTPHALIA.

SIEBENGEBRIGE, EIFEL, ETC.

Collini............ Observations sur les Monts Volcaniques. Manheim, 1781. Gives an account of the volcanic country near the Rhine.
The same Author in 1775 had published "Observations sur les Agates et Basaltes."
Sir W. Hamilton, Phil. Transactions for 1778, Part 1, gives a short account of the volcanic rocks of the Rhine.
Nose .... Orographische Briefe über das Siebengebirge. 2 vols. 4to. 1789. A most full, though tedious and desultory account of the neighbourhood of the Rhine.
Humboldt ...... Beobacht. über einigen Basalten am Rhein. 1700.
Forster .... Ansichten des Niederrheins. 1791.
Behr .... Coup d'œil sur les anciens Volcans éteints des environs de la Kill Supérieure, &c. Paris, 1802, 8vo.
Dettier .... Sur les Volcans de la Kyll. Paris, 1804.
Wurzer .... Taschenbuch des Siebengebirge. Köln, 1815.
Camper .... Reise nach den Vulkanen des Niederrheins, edited by Von Mark.

Keferstein ...... Beiträge zur Geschichte und Kenntniss des Basaltes. In Schriften der Naturforsch. Gesellschaft zu Halle, 1819. Gives an account of the Eifel Volcanos. See also the Numbers of his "Teutschland geologisch-geognostisch dargestellt."

Steininger ...... Geognostische Studien. 1819.
Erloschenen Vulkane in der Eifel. 1820.
Geognostische Bemerkungen über die Basalt-gebilde des westlichen Deutschlands. 1820.
Neue Beiträge. 1821.
Gebirgskarte. 1822.
Also various Memoirs in the work entitled "Das Gebirge in Rheinland Westphalen," edited by Professor Nöggerath of Bonn, 4 volumes of which are now published.

Van der Wyck. Uebersicht d. Rhein u. Eifel erlosch. Vulkane. 1826.
Ditto. Leonhard's Jahrbuch, 1836.

Boué .... Journ. de Physique, 1822, vol. 94. pp. 297, 345; vol. 95. pp. 31, 88, 173 and 275.
Geognostische Gemäld. Deutschland. 1829.

Oeynhausen und Dechen. Geogn. Umriss. d. Rheinlander. 1825.

Hibbert .... On the Extinct Volcanos of the Basin of Neuwied on the Lower Rhine. London, 1832.

Horner .... On the Geology of the Environs of Bonn. Transactions of the Geological Society, vol. 4, new series.

Texier............ On the Siebengebirge. Bull. Géol. de France pour 1833.

Zehler, T. G. ... Das Siebengebirge. 1837.

2. HESSIA.

RHÖNGEBIRGE, HABICHTSWALD, VOGELSGEBIRGE, WESTERWALD, ETC.

Heller............ In Möll's Annal. der Berg. und Huttenkunde, vol. 1. On the Rhöngebirge.

Voigt .... Beschreibung des Hochstifts Fuld. 1783. Relates to the Rhöngebirge.
Mineralogischen Reisen von Weimar über den Thuringerwald, Rhöngebirge, &c. 2 vols. 8vo. 1802.
Kleine Miner. Schriften. Weimar, 1802. Relates to the basalts of Hessia.

Jacob und Hoff. Der Thuringerwald für Reisende geschildert. 2 vols. Gotha, 1807–1812. Gives an account of the basalts on the south-west side of Thuringerwald.

Sartorius......... Die Basalte von Eisenach. 1802. Contains the first notice of the curious dykes, mentioned p. 99–100.
Geognostische Beobacht. Eisenach. 1823.
Nachtrag. 1823. All these memoirs relate to the basalts about Eisenach.

Hoff, Von ...... Magazin der Berlin. Gesellschaft Naturforschender Freunde, 5th year, p. 347, on the Blaue Kuppe near Eschwege—with a plate. See also De la Beche's Geological Memoirs.
On the Dyke of Hörsel near Eisenach. Same work, 7th year.

Raspe .... On some German Volcanos. London, 1776. Relates to the Habichtswald near Cassel.
Catalogue des Min. du pays de Cassel. 1808.

Reiss .... Beobacht. über einige Hessische Gebirgsgegende. Berlin, 1790.

Becher .... Ueber die Nassauische Gegende. 1786. Gives an account of the singular porphyries associated with clay-slate about Dillenburg.

Leonhard ...... Taschenbuch for 1822. Gives an account of the rocks about Heidelberg.
Rhöngebirge Zeitsch. f. Min. 1827, p. 97.

Cotta .... Reise durch der Rhöngebirge. Leonhard's Jahrb. vol. 4, 1833.

Schaub, T. ...... Phys. min. Beschreib. d. Meissners. 1799.

Klipstein, Ph.... Vogelsgebirge. 1790.

Klipstein, Aug. Various papers on Vogelsgebirge and Rhöngebirge. Leonhard's Jahrb. f. Min. und Arch. f. Min. d. Karsten.
Sir Alex. Crichton. On some parts of the Taunus M. Geol. Trans. vol. 2, new series, 1826.
Wille, G. A....... Geogn. Beschreib. d. Gebirgmassen zwischen Taunus u. Vogelsgebirge. 1828.

3. SWABIA.

BRISGAU, BLACK FOREST, ETC.

Leonhard ...... Taschenbuch for 1823, gives an account of the rocks of Brisgau, and those near Constance.
Boué .... In the Annales des Sciences Naturelles for August 1824, gives an account of the same rocks.
Saussure......... In the Journal de Physique, vol. 44, has also treated of them.
Pictet .... has inserted, in the Transactions of the " Société d'Histoire Naturelle de Genève," a short notice respecting the same country.
Razoumofsky... In the Bergmannisches Journ. vol. 5. p. 188, has spoken of them.
Wiedenman ... (vol. 6 of the same work) has commented upon the foregoing paper.
Eisenlohr, Otto Geogn. Beschreib. d. Kaiserstuhls bei Friburg in Brisgau. 1829.
Fromherz ...... Geognosy of the Schönberg in the Brisgau.

4. BAVARIA.

FICHTELGEBIRGE, ETC.

Flurl .... Beschreibung von Baiern. 1792.
Goldfuss und Bischof. Beschreibung der Fichtelgebirge.

5. SAXONY.

ERZGEBIRGE, ETC.

Charpentier ... Min. Geographie der Chursachsischen Landes. Leipsic, 1778.
Daubuisson...... On the Basalts of Saxony. Translated by Neill. Edinburgh, 1814.
Boué .... Basalts of Riess or Riessgau. Zeitsch. f. Min. 1829, p. 517.
Cotta .... Ditto. Jahrb. f. Min. 1834, p. 307.
Virth, Von ...... Ditto. Jahrb. f. Min. 1835, p. 169.

6. SILESIA.

RIESENGEBIRGE, ETC.

Buch, Von ...... On the Environs of Landeck. Translated by Dr. Anderson, 1810. Pronounced to be the best Essay in Mineralogical Geography that had appeared in Germany.
Oeynhausen ... Versuch einer geognostischen Beschreibung von Obersilesien. 8vo. Essen. 1822.
Singer............ Basalts of the small Schneegrube (Riesengebirge). Archiv f. Bergb. d. Karsten, vol. 3. p. 86–89.

7. BOHEMIA.

MITTELGEBIRGE, ETC.

Reuss .... Orographie des Nordw. Mittelgeb. Dresden, 1790.
Sammlung Naturhist. Aufsatze, 1796.
Min. und Bergmann. Bemerk. über Bohmen. Berlin, 1801.
Lindacher ...... In Sammlung. Phys. Aufsatze von Mayer. 1791. Shows the volcanic origin of the basalt of Wolfsberg in the Circle of Pilsen.
Selb .... N. Schrift. d. Ges. Naturf. Fr. Berlin. Vol. 4. p. 395.
Razoumofsky, Graf. Alpina, vol. 3. p. 313. One of the first who acknowledged the vulcanicity of the sphærolites of Hegau in 1788.
Neumann ...... Leonhard's Zeitschrift, 1825, p. 289.
Cotta .... Der Kammerbuhl bei Egra. 1833.
Göethe .... In his " Morphologie," also gives a description of the same little volcano.

Berzelius ...... Analysis of the Waters of Carlsbad, alludes to it.
Reuss, H. E. ... Umgebungen von Töplitz. 1840.
Zippe .... Geology of Bohemia. Mem. Roy. Soc. of Prague, vol. 4, 1845.

HUNGARY, TRANSYLVANIA, STYRIA, BANNAT.

Fridwalazky ... Mineralogia magni Principatus Transylvaniæ Claudiop. 1767.
Scopoli .... Crystallographia Hungarica. 1776.
Born .... Briefe. Dresden, 1774. Also translated into French. Relate to the Bannat of Temeswar.
Fichtel .... Min. Beiträge von Siebenburgen. 1780.
Bemerkungen über den Karpathen. 1791.
Ferber............ Abhandlungen über die Gebirge in Ungarn. 1780.
Bredetzki ...... Beiträge zur Topographie von Ungarn. 3 vols. 8vo.
Buchholz ...... Reise auf die Karpatischen Gebirge. Ungrisches Magazin, t. 4, 1787. The same author published anonymously another Description of the Carpathians, with some remarks on Hungary. 1783.
Townson......... Travels in Hungary. 4to, 1797.
Esmark .... Beschreibung einer Reise durch Ungarn. 1798. Represents the trachytes of Hungary as of aqueous origin.
Asboth .... Reise von Keszthely nach Vesprim. Wien, 1803. Relates to the basalts of Lake Balaton.
Leonhard's...... Taschenbuch, 1816, p. 413. Memoir on some parts of Hungary by Jonas.
Taschenbuch, 1813, 1815, 1816, 1817, 1819, and 1820, for different Memoirs by Zipser.
Zipser............ has also published "A Manual" of the Mineralogy of Hungary. Œdenburg, 1817.
Bright............ Travels in Hungary. 4to, 1818. Chiefly agricultural.
On the Hills of Badacson, &c. Geol. Trans. for 1819.
Beudant .... Voyage en Hongrie. 3 vols. An excellent work, but one that would have been benefited by compression.
Buch, Von ...... Transactions of the Berlin Academy. On the Volcanos of Styria.
Anker, Math. ... Kurze Darstellung d. mineral. geognost. Gebirgs-verhaltnisse der Steyermark. 1835.
Partsch, P....... Environs of Gleichenberg. Beschreibung d. Quellen bei Gleichenberg, 1836, p. 52–79.
Sedgwick and Murchison. On the Structure of the Eastern Alps. Trans. of the Geol. Soc. vol. 3, new series.
Boué, A.......... Transylvania. Mém. Soc. Géol. Fr. 1834, vol. 1. p. 2.
Grimm .... Der Berg Budoshegy in Siebenburgen. Leonhard's Jahrb. 1837.

ITALY.

VENETIAN STATES.

Arduini, J. ...... His Observations on the Euganean Hills and Vicentin, in which their volcanic origin is asserted, were first published in 1765.
Other publications of his appear in the Saggi Scientifici, &c. dell. Accademia del Padova, and in the Atti dell. Accademia di Sienna, 1760–61.
He also published, 1774, "Saggio Mineralogico di Lithogonia e Orognosia." Padova, 4to.
Raccolta d. memorie mineralog. chimice. Venise, 1775.
A German Translation of some of his works appeared at Dresden in 1778, entitled "Sammlung Mineral. Abhandlungen."
Salmon .... On the Euganean Hills. Journal de Physique, vol. 53.
Strange .... Phil. Trans., vol. 65, for 1775.
Fortis .... Mémoires pour servir à l'Histoire Naturelle de l'Italie. Paris, 1802. Relates to the Vicentin, which he shows to be of volcanic formation.
Brongniart..... Sur les Terrains calcareo-trappéens du Vicentin. 1823. Relates chiefly to the shells contained in the Tertiary rocks.

Maraschini...... Saggio Geologico sulle Formazione delle Rocce del Vicentino. Padova, 1824.
Fleurial de Bellevue. Journ. de Physique, 1790. Maintains the igneous origin of the rocks of Grantola.
Pini............... Sul alcuni Fossili singolari della Lombardia. 1790. On the rocks near Grantola.
Gautieri......... Confutatione dell. opin. di alcuni Mineralogiste sulla Volc. di Mont. di Grantola. 1807.
Pollini .... Descrittione del Monte Baldo.
Sulle Formazioni del Vicentino. 1824.
Buch, Von ...... Ann. des Sci. Naturelles, 1827. On the dolomites of Lugano.
Rio, Nicol de ... Orittologia Euganea. 1836.
Savi............... Memorie per servire allo studio &c. della Toscana. Pisa, 1839. Gives many details respecting the serpentine and other veins in the district of Volterra.
Pilla .... Saggio comparativo dei Terreni che compongono il suolo d' Italia. Pisa, 1845.

CENTRAL ITALY.

Targioni Tozzetti Relatione dei Viaggi in Toscana. Firenze, 2 vols. 8vo. The same translated into French. Paris, 1792.
Ferber............ Histoire Naturelle d'Italie, traduite par Dietrich. Strasbourg, 1778. Translated into English, 1776.
Santi .... Viaggi. 3 vols. Pisa, 1795–98. The last volume relates to the Monte Amiata. The same in French. Lyons, 1802.
Buch, Von ...... Reise durch Italien, &c. 1809.
V. Procac. Ricci. Viaggi ai Vulcani spenti d' Italia nello Stato Romano verso il Mediterraneo. 1814.
Desc. metodica di alquanti Prodotti dei Vulcani spenti nello Stato Romano. 1820.
Gmelin .... Dissert. de Hauyne. Heidelberg, 1816. Gives a map of the craters about Albano.
Kephalides...... Reise durch Italien und Sicilien. 2 vols. maps, 1818. 8vo, Leipsic.
Breislac .... In his "Voyage en Campanie," has a chapter on the Volcanos of Rome.
Brocchi .... Conch. Subapennina. 4to, vol. 2. Milano, 1814.
Catalogo Ragionato di una Raccolta di Rocce. Milano, 1817.
Suolo di Roma. 1820.
Prystanowsky... Ueber die Ursprung der Volcanen in Italien. Berlin, 1823. (Neptunist.)
There are also several Memoirs, by Brocchi and others, in the Biblioteca Italiana, on Central Italy.
Professor Hoffmann, in Bunsen's work on the Antiquities of Rome, entitled "Beschreibung der Stadt Rom," has given an account of the physical structure of that neighbourhood.

SOUTHERN ITALY.

Sorrentino ...... Istoria del Vesuvio. Napoli, 1734.
Duca del Torre. Istoria e Fenomeni del Vesuvio. 1755–1768. 4to, Napoli.
Gioeni............ Litelogia Vesuviana.
Sir W. Hamilton. Campi Phlegræi. Naples, 1776, fol.
Supplement to ditto, 1779. First published in the Philosophical Transactions.
Dolomieu ...... Sur les Iles Ponces. 1788.
Breislac .... Voyage en Campanie. 2 vols. 8vo. 1801.
Buch, Von ...... Geognostische Reise. Berlin, 1809. Vol. 2 relates to Rome and Naples.
Menard de la Groye. Journ. de Phys. vol. 80, on the Eruption of 1813, &c.
Lippi .... Sotteraneo di Pompeo e di Ercolano, opere delle alluvioni, è non dell' Eruzione del Vesuvio. 1819.
Odesleben ...... Reise in Italien. 2 vols. 1821. Relates to Naples, Rome, and the Euganean Hills. (Wernerian.)

Necker .... Sur le Monte Somma. In the Transactions of the Natural History Society of Geneva, vol. 2.
Monticelli et Covelli. Storia di Fenomeni del Vesuvio. Napoli, 1823–25.
Göthe .... Zur Naturwissenschaft. The 2nd vol. contains an account of the geological phænomena presented at the Temple of Puzzuoli.
Canonico de Jorio. A pamphlet on the same subject.
See also sundry papers by Brocchi and others on this part of Italy—especially on Mount Vultur and the Lago di Ansanto in Biblioteca Italiana, &c.
Prof. J. Forbes. Series of Memoirs on the vicinity of Naples. Brewster's Journal of Science for 1828–29.
Auldjo............ Sketches of Vesuvius. 1833.
Hamilton ...... Geographical Journal, on Lago d'Ansanto. Vol. 2. 1832.
Scrope............ Volcanic district of Naples. Trans. Geol. Soc. vol. 2, new series, 1829.
On the Ponza Islands. Trans. Geol. Soc. vol. 2, new series, 1829.
Lyell .... Principles of Geology, vol. 1, 1830; vol. 3, 1833,
Pilla .... Spettatore del Vesuvio, e di Campi Flegrei. 1832–33.
Bulletino Geològico, &c. 1834.
Daubeny......... Phil. Trans. 1835, on the Eruption of Vesuvius in 1834.
On the Lago d'Ansanto and Mount Vultur in Apulia. Trans. of the Ashmolean Society, 1835.
Abich .... Ueber die Natur der vulkanischen Bildungen, Braunschweig, 1841, contains many details respecting Rocca Monfina and Mount Vultur.
Scacchi .... Sundry Memoirs, chiefly mineralogical. 1842–43.
Pilla .... On Rocca Monfina. Bull. de la Soc. Géol. de France, 1842.
Daubeny......... On the Site of the ancient City of the Aurunci, and on the Volcanic Phænomena which it exhibits. Trans. of the Ashmolean Society, 1846.
Babbage......... On the Temple of Serapis. Quarterly Journal of the Geol. Soc. 1847.

SICILY.

Brydone......... Travels in the Two Sicilies. 1774.
Borch............ Mineralogia Siciliana. 1780.
Lettres sur la Sicile et sur Malte. Turin, 1732. 2 vols. 8vo. with a volume of plates.
Spallanzani...... Voyages dans les deux Siciles. Traduits de l'Italien. 6 vols. 8vo. Paris, An. 8 (1800).
Recupero ...... Storia Naturale dell' Etna. 2 vols. 4to. Catania, 1815.
Ferrara .... Campi Flegrei della Sicilia. Messina, 1810.
Descrizione dell' Etna. 1818.
Memorie sopra il Lago Naftia, e sopra l'Ambra Siciliana. 1805.
Sopra Tremuoti della Sicilia in Marzo 1823.
Gemellaro ...... Giornali dell' Eruzione dell' Etna avvenuta 1809. Catania, 1816.
Sopra alcuni pezzi di Granito,&c. trovati presso alla cima dell' Etna.
Moricand ...... Observ. Géognostiques. Journ. Britann. 1819. Translated in Gilbert's Annalen, 1820.
Brocchi .... In Bibl. Italiana, vol. 20, on the Cyclopean Rocks.
Gourbillon ...... Voyage à l'Etna. Paris, 1820.
Sayve .... Voyage en Sicile. 1822.
Smith .... Tour in Sicily. 4to, 1824.
Daubeny......... Sketch of the Geology of Sicily in the Edinburgh Philosophical Journal, 1825; reprinted in Silliman's American Journal, 1826.
The Gioenean Society, Transactions of, contain several Memoirs on the Volcanic Phænomena and Volcanic Mineralogy of Sicily, by Gemellaro, Maravigna, &c.
Maravigna, C.... Materiali per la compilazione della Orittognosia Etnea. Catania, 1835.
Dr. John Davy. Phil. Trans. 1832, on the new island off Sicily.

Prévost, Const. Sur l'Ile Julia. Mém. Soc. Géol. France, vol. 2. part 1. p. 91.
Lyell .... Principles of Geology, vol. 3rd, Val di Bove.
Elie de Beaumont et Dufrénoy. Mémoire sur l'Etna, in the "Mémoires pour servir" above quoted.
Hoffmann, F. ... Geognostische Beob. Berlin. 1839, contains perhaps the most complete account of the Geology of Sicily.
Capozzo .... Memorie su la Sicilie, vol. 3. Palermo, 1840.
Sartorius de Waltershausen. Ueber die Submarinen Vulkanischen Ausbruche des Val di Noto, in Vergleich mit verwandten Erscheinungen am Ætna. Gottingen, 1846, 8vo.
On Mount Etna. Atlas now in the course of publication.

LIPARI ISLANDS.

Dolomieu ...... Sur les Iles de Lipari. 1783.
See also Spallanzani, Voyages dans les deux Siciles, Ferrara, Campi Flegrei, &c.
Hoffmann, Frederic. Poggendorff's Annalen, vol. 26, 1832.

SPAIN AND PORTUGAL.

Link .... Geolog. Bemerkungen auf einer Reise durch das S.W. Europa. 1800.
Palassou......... Nouveaux Mémoires sur les Pyrenées, 1823, contain an account of the Volcanos of Catalonia by the Abbé Pourret.
Lyell .... On the Volcanos of Catalonia (Principles of Geology).
Maclure .... Ditto, Journ. de Physique, 1808, vol. 66. p. 219.
Cook (Widdrington). Sketches in Spain. 1834.
Sharpe .... On Lisbon. Geol. Trans. vol. 6, new series.
Eschwege ...... Lisbon. N. Arch. f. Min. vol. 5. p. 365; and Leonhard's Jahrbuch, 1834.

ICELAND.

Von Troil ...... Letters. London, 1770. Giving an account of Sir Joseph Banks' Journey.
Olafsen .... Reise durch Island (Teutsche Uebersetz). Kopenhagen, 1774.
Mackenzie ...... Travels. Edinburgh, 4to, 1811.
Hooker .... Recollections. 2 vols. 8vo, 1813.
Henderson ...... Residence in Iceland. 2 vols. 8vo, 1819.
Garlieb .... Island rucksichtlich seiner Vulkane. Freiburg, 1819, 8vo.
Menge............ Edinburgh Philosophical Journal, vol. 2.
Gliemann ...... Geographische Beschreibung von Island. 1824.
Krug von Nidda. Karsten's Annalen, vol. 9; and Jameson's Journal, 1837.
Robert .... In Gaimard's Expédition Scientifique. Paris, 1840; with a folio atl.
Bunsen .... Auszug einer Schreibens aus J. J. Berzelius. 1846.
Ueber den Zusammenhang der Pseudovulk. Erschein. Islands. Liebig's Annalen, 1847.
Beitrag zur Kenntniss des Islands Tuffgebirgen. Ditto.

GREECE, TURKEY, AND ARCHIPELAGO.

Tournefort ...... Voyage in the Levant. 2 vols. 4to. London, 1718.
Philosophical Transactions for 1708 and 1711. Island of Santorino.
Choiseul Gouffier. Voyage Pittoresque de la Grèce. 2 vols. folio.
Clarke............ Travels in various parts of Europe, 1st volume.
Dodwell .... Travels in Greece. 4to, 1815.
Andreossi ...... Voyage à l'Embouchure du Mer Noire. Paris, 1818.
Dr. J. Davy ... On a Curious Phænomenon in the Isle of Cephalonia. Ed. New Phil. Journ. vol. 2, 1835.
Virlet et Boplaye. Expédition Scientifique de Morée. 1839.
Ross .... Reise aus den Griech. Inseln. 1840.

Fiedler .... Reise durch Griechenland. 1841.
Boué .... Turquie en Europe. Vol. 4, 1840.
Viquesnel ...... Mém. de la Soc. Géol. de France, 1842 and 1846.

ASIA MINOR.

Webb .... On the Troad. Biblioteca Italiana.
Ainsworth ...... Researches in Babylonia and Assyria. 1838.
Hamilton ...... On part of Cappadocia. Geol. Trans. vol. 5, 1840.
Hamilton and Strickland on the Geology of the W. part of Asia Minor. Geol. Trans. vol. 6, 1841.
Hamilton ...... Travels in Asia Minor. London, 1842.

SYRIA, THE HOLY LAND, AND ARABIA.

Niebuhr .... Beschreibung von Arabien. Copenhagen, 1772, 4to. Translated into French, 1773.
Sestini........... Voyage de Constantinople à Bassora en 1731. Translated from the Italian.
Briefen über der Vulkanen von Syria und Mesopotamia. Deutschen Mercur.
Volney .... Voyage en Syrie et Egypte. 3rd edit. Paris, 1800.
Olivier............ Voyage dans l'Empire Ottoman. 3 vols. 4to. 1807.
Morier .... Journey through Persia. 2 vols. 4to. 1808.
Seetzen .... Researches, published under the title of "A brief Account of the Countries adjoining the Lake Tiberias, the Jordan, and the Dead Sea." London, 1810; *scarce*. Also in Zach's Correspondenz, vol. 13–18.
Buckingham ... Travels in Palestine. 1821.
Burckhardt...... Travels in Syria. 1822.
Robinson ...... Biblical Researches in Palestine.
Russegger ...... Russia, Syria, Palestine. 1843.
Ainsworth ...... Researches in Assyria, above quoted.
Burr .... On Aden. Geol. Trans. vol. 6.
Wilson .... Lands of the Bible. 2 vols. 1847.

PERSIA AND THE ADJOINING COUNTRIES.

Pallas .... Travels in the Russian Empire. 5 vols. 4to. 1788.
Reineggs......... Beschreibung des Kaukasus. Gotha und St. Petersburg, 1796.
Klaproth......... Reise in dem Kaukasus. Halle und Berlin, 1812.
Engelhardt und Parrot. Reise in dem Krym und Caucasus. Berlin, 1815.
Sir Ker Porter...Travels in Georgia. 4to. 1822.
See also Tournefort, Clarke, and others.
Kinneir's......... Travels in Asia Minor.
Morier's .... Travels in Persia.
Kuhn et Barotsi de Els. On the Lake Goktschar. Journal of St. Petersburg, 1829.
Parrot............ Reise zum Ararat. 1834.
Dubois de Montpereux. Voyage autour du Caucase. Paris, 1838. 6 vols. 8vo, with a folio atlas.
Eichwald ...... On the Caucasus.
On the Neighbourhood of the Caspian. Ed. New Ph. Journ. 1833.
Wagner, Moritz. Ararat. Gazette of Augsburg, 1844.
Abich .... Ueber die Geognos. Natur der Armenischen Hochlandes. 1844. Bulletin de la Classe Phys. de l'Académie de St. Pétersbourg. Translated in the Quarterly Geol. Journal.
Koch .... Reisen. 1846.
Lieut. Baird Smith. On Indian Earthquakes. Journ. Asiatic Society of Bengal, vol. 12.
Malcolm's ...... Central India, vol. 2nd, Appendix.
Captain Grant... Geol. Trans. vol. 5, new series.

ISLANDS OF ASIA.

Valentyn......... Oud en nieuw Ost-Indien. 9 vols. 1724; *scarce*.
Kraskeninicoff. History of Kamtschatka and the Kurule Isles. Translated from the Russian into French, 1767.
Marsden......... Sumatra. 3rd edition, 1811.
Sir S. Raffles ... Java. 2 vols. 4to. London, 1817.
Kotzebue ...... Voyage of Discovery during the years 1815–1818. Translated into English, 1821.
Stewart .... On Sumbaya. Trans. Phil. Soc. Bomb. 1819, vol. 1.
Don Ildefonso de Aragon. Desc. de la Ysla de Luçon. 1819.
Barande, I. T. S. Philippines. Anales de Minas. Madrid, vol. 2. p. 197.
Colebrooke...... On Barren Island. Asiat. Researches, vol. 4.
Adam .... On Barren Island. Trans. of the Asiat. Soc. of Bengal, vol. 1.
Reinwardt ...... Java. Verh. der Batav. Genootsch, 1823, vol. 9.
Leschenault ... Java. Annal. d. Voyag. 1842.
Boon Mesch, Van der. De Incendiis montium Javæ. 1826.
Blume............ Forty Volcanos and Eruptions of Mud in Java (Ann. Berghaus, 1832).
Hardie .... North Port of Java. Bull. Soc. Géol. Fr. vol. 4. p. 218.
Junghuhn ...... Reise nach Java. Magdeburg, 1845.
Postals .... Ueber die Vulkane der Halbinsel. Kamtschatka. Leonh. Jahrb. 1836.
Erman............ Kamtschatka. Reise um die Welt.
Titsingh's ...... Illustrations of Japan.
Siebold .... Voyage au Japan, 1838.
Horner .... Geology of the Indian Archipelago. Leonhard's Jahrbuch, 1839.
Dr. S. Müller. Celebes, Amboina, Banda. Verh-doer de Naturl. Gesch. Ind. Neerland. 1841.

SOUTH-SEA ISLANDS.

Sandwich.

Forster .... Observations during a Voyage round the World. London, 1778.
Ellis .... Tour in the Sandwich Islands. 1826.
Stewart, Ch. ... Hawaii (Owyhee). Amer. Journ. of Science, 1826, vol. 20. p. 228, or Edin. New Phil. Journ. 1827.
Kelley, E. G. ... Geology of Owyhee. Amer. Journ. of Science, 1841. vol. 40. p. 117.
Goodrich, Jos... Geology of Owyhee, 1834, vol. 25. p. 199.
Douglas .... Journ. of the Roy. Geograph. Soc. London, 1834, vol. 4.
Chevalier ...... Voy. de la Bonite, Partie Géol. 1844, pp. 183–213.
Anderson ...... Journal of a Missionary round Hawaii. Boston, 1825.

St. Paul or Amsterdam I.

Augsburg Gazette, 1844, 25th Aug. Beiträge, p. 1900.

Otaheite.

Hoffman, E. ... Arch. f. Min. Karsten, 1829, vol. 1. p. 259.
Duperrey......... Voyage. In the interior of the Island.

Other Parts of the Pacific.

Buch, Von ...... On Van Diemen's Land, in the Magazin der Naturforschender Freunde zu Berlin.
See also Capt. Cook's, Bligh's, Dampier's, Vancouver's, and La Billardière's Voyages.
Chevalier, E. ... South Shetland. Voy. aut. du monde de la Bonite, Partie Géol. 1844, p. 54.
Ladrones. Voyage de la Bonite, Partie Géol. 1844, p. 217.
Enderby......... Various Isles. Journ. Geogr. Soc. London, vol. 9. p. 522.

Antarctic Continent.

Capt. Sir James Ross. Voyage of Discovery. 1846.
Dumont D'Urville. Exploring Expedition.
Wilcke .... Ditto.
Marchand ...... Ditto.
Krusenstern's... Voyage round the World.
Briton's .... Voyage to Pitcairn's Island.
Darwin .... Volcanic Islands. 1844.
Dieffenbach ... New Zealand. 1845.
Strzelecki ...... Phys. Desc. of New South Wales. 1846.

AFRICA.—Islands.

Buch, Von ...... In the Transactions of the Academy of Berlin, has given remarks on the Canary Islands, especially Lancerote (Ann. 1818–19), Teneriffe (Ann. 1820–21).
Bory St. Vincent. Voyage aux Iles d'Afrique. 3 vols. 4to. Paris, 1804. On the Isles of France and Bourbon.
Dr. Webster ... Boston, 1820. Account of the Azores.
Ehrman .... Weimar, 1807. On St. Helena.
Beatson's ...... Tracts on St. Helena. 4to. London, 1816.
Annales des Mines, 1824, gives some account of Basalts in Senegal, from the observations of a Frenchman who died there.
Bowdich......... In his Posthumous Work, London, 1825, has given a geological description of Madeira and Porto Santo.
See also Humboldt's Personal Narrative, vol. 1, for Teneriffe.
Du Petit Thouars. Tristan d'Acunha (Mélanges de Botaniq. et de Voyage). Paris, 1811.
Buch, Von ...... Voyage aux Iles Canaries. This important work not only communicates the results of his personal observations on the Geology and Botany of the Canaries, but likewise contains a brief but luminous account of all other existing Volcanos,—a mine of information from which I have profited largely in various parts of the present volume. 1825. French Transl. 1836.
Taylor........... Mount Peter Botte, Mauritius. Journ. of the Geogr. Soc. Lond. vol. 3. part 1. p. 99.
Campbell, Robt. Isle of Ascension. Edin. Phil. Journ. 1826, vol. 14. p. 47.
Serle, Robert F. On the Geognosy of St. Helena. 1834. In 4to. oblong.
Webb et Berthelot. Hist. Nat. des Canaries. 1836.
Vargas de Bedemar. Resumo de Observacoes Geolog. al Ilhas da Madeira, Porto Santo e Acores. 1837.
Macauley ...... Madeira. Physical Geography. Ed. New Phil. Journ. vol. 29, 1840.
Smith (of Jordan Hill). Geol. Trans. 1841. Geology of Madeira.
Darwin .... Volcanic Islands. 1844.
Deville, Ch. ... Recherches Géolog. sur les Iles de Teneriffe et de Gogo. Paris, 1845.
Hunt .... Geology of St. Mary's Island, one of the Azores. Quarterly Geol. Journ. No. 5.

AFRICA.—Continent.

D'Abbadie ...... Bull. Soc. Géol. Fr. vol. 10. p. 122. Abyssinia.
Ferret et Galinier. Voyage en 1839. Compt. R. Ac. de Sc. 1844, 17 Juin. Ditto.
Rocher d'Hericourt. Travels. Sur les Volcans de l'Abyss. mérid.
Rüppell, Ed. ... Reise in Abyssinien, 1838–40.
Geologie. Mus. Senkenberg, vol. 1. c. 3. p. 286.
Schimper, Will. Samen and Tacazze in Abyssinia. Augsburg Gazette, 1843.
Voyage of Hornemann and Corresp. de Zach. 1800. Fezzan.
Ehrenberg, Rüppell, Russegger, and St. John's Travels. Egypt.
Ehrenberg and Hemprich. Travels. Borders of the Red Sea.

ANTILLES.

Torrubia .... Historia Naturale d'Española. Madrid, 1754.
Dauxion Lavaysse. Voyage à l'Ile de Trinité.
Le Blond ...... Voyage aux Antilles.
Nugent .... In the Geological Transactions, vol. 1. old series, and vol. 1. new series.
Cortes............ Journal de Physique, tom. 70.
Moreau de Jonnes. Statistique des Antilles. Paris, 1822.
Sir H. De la Beche. Geology of Jamaica. Geol. Trans. vol. 2. new series.
Dupuget .... Journ. des Mines, vol. 6. p. 46. Martinique.

AMERICA.

North America.

Nicollet .... Pseudo-Volcanos? on the Upper Missouri. American Journ. of Science, 1843, vol. 45. p. 154.
Farnham, Thos. Travels, &c. 1843.
Gairdner......... Volcanos N. of Vancouver, Oregon Territory (Ausland, 1836, p. 404).
Fremont, Capt. Narrative of the Exploring Expedition to the Rocky Mountains in 1842, and to Oregon, 1845.

Mexico.

Humboldt ...... Political Essay on New Spain.
Researches, &c.
Essai sur le Gisement des Roches.
Glennie, W. ... Ascension to Popocatepetl. Phil. Mag. 1828, June, p. 449.
Schiede (De) and Deppe. Volcano of Orizaba. Hertha, 1829, vol. 13. p. 117.
Galeotti .... Voyage au Coffre de Perote. Bull. Ac. Roy. de Bruxelles, 1836.
Burkart, Jos. ... Aufenhalt u. Reisen in Mexico, 1836.
Schleiden, Emile. Jorullo (views opposed to Humboldt: no elevation, but a gradual covering of the soil by eruptive matter). Zeitschrift für die Fortschritte der Geographie de Froriep. Weimar, 1847, vol. 2. p. 14–27.

South America.

Alonzo d'Ovaglia. Hist. relaz. del regno di Chili. Roma, 1646.
Condamine...... Mes. des trois premiers deg.
Molina .... Histoire Naturelle de Chili, translated into English, 1808.
Humboldt ...... Personal Narrative.
Gisement des Roches.
Volcanos of Guatemala. Phil. Mag. 1827.
Bailey, Col....... On Guatemala. London, 1823.
D'Orbigny, Alcide. Voyage dans l'Amériq. mérid.
Meyen............ Travels. Relates to Peru.
Poeppig .... Travels in Chili, Peru, &c. 1835.
Domeyko ...... Chili. Ann. des Mines, 1846.
Gay............... Observations on Chili. Compt. R. Ac. de Sc. Paris, 1838.
Castelnau's...... Recent Journey. Peru.
Boussingault and Rivero. Ann. de Chim. 1835. Quito and New Grenada.
Roulin............ On Colima.
Hall, Col. ...... Pichincha. Brit. Assoc. Edinb. 1834.
Wisse .... Pichincha. N. Ann. de Voy. 1845, vol. 3. p. 106. Compt. R. Ac. de Sc. 1845, vol. 20. p. 1785.
Pentland......... Geograph. Journ. vol. 5. Outline of the Bolivian Andes.
Miers .... Travels in Chile, 1826.
Darwin .... Observations on South America. 1846.
Sir James Ross. Voyage of Discovery. 1846.

EARTHQUAKES.

Beuther .... Compendium Terræmotuum. Strasburg, 1601.
Bernhertz ...... Terræmotus (a Register of Earthquakes). Nurnberg, 1616.
Dr. Vincenzo ... Notizie istoriche de Tremuoti. Napoli, 1688. A Chronological and Historical Account of Earthquakes.
Seyfarth .... Allgemeine Geschichte der Erdbeben. Leipsic, 1756.
Bertrand......... Mémoires Historiques sur les Tremblemens de Terre. La Haye, 1757.
Bertholon ...... Journal de Physique, tom. 14.
Mitchell .... Phil. Trans. 1760. The same work contains several other Memoirs on Earthquakes by Dr. Stukeley, &c., especially about the middle of the last century.
Vivenzio .... Istoria e Teoria de Tremuoti avvenuti nella Provincia della Calabria, &c. di 1783–1787. Napoli, 1788.
Cotte .... Tableau Chronologique des principaux Phénomènes Météorologiques observés en différens pays depuis 33 ans, &c. Journal de Physique, tom. 65.
Dolomieu ...... On the Calabrian Earthquake.
Trans. Roy. Acad. of Naples on ditto.
Vivenzio .... Storie di Tremuoti, 1783.
Walther .... Erdbeben und Vulkane Physisch dargestellt, 1805.
Kries .... Die Ursachen der Erdbeben, 1826.
Keferstein ...... Teutschland, vol. 4. part 3. List of Volcanic Eruptions and Earthquakes, in chronological order. Weimar, 1827.
Lyell .... Principles of Geology, vols. 1 and 3, 1830–1833.
Miss Graham ... On the Earthquake of Chili. Trans. of Geol. Soc. vol. 1. new series.
Hoffman .... Hinterlassene Schriften, 1838.
Biot................ On the Earthquakes in China. Ed. New Ph. Journ. vol. 29, 1840.
Darwin .... Geol. Trans. vol. 1. new series.
Hopkins .... Researches in Physical Geology. Cambridge Phil. Trans.
Mallett .... Trans. Roy. Irish Acad. Dynamics of Earthquakes. 1845.
Hamilton ...... On recent Earthquakes in South America. Ed. New Ph. Journ. vol. 30, 1841.
Milne .... On Earthquake Shocks in Great Britain. Ed. New Ph. Journ. 1842–1843.
Hoff, Von ...... Catalogue of Earthquakes from 1821 to 1827. Ann. de Poggendorf, vol. 18, 1821.
Ditto. Chronik der Erdbeben und Vulkan, 1841. 2 vols. 8vo.
Boegner, T....... Das Erdbeben und seine Erscheinungen. Frankfurt-on-the-Maine, 1847, 8vo; with a map of the Earthquake of 29th July, 1846.

THERMAL WATERS.

[N.B. In this List only those Works are included which afford information on the physical phænomena of Thermal Waters, and appear of some interest in a scientific point of view.]

Carrere .... Catalogue raisonné des ouvrages sur les Eaux Minérales. 1785.
Cordier, M....... Sur le Chaleur centrale. Ann. du Muséum, 1817.
La Place .... Ditto. Thermal Waters. Journ. de Phys. 1820, vol. 90. p. 403.
Keferstein ...... Teutschland, 1822, vol. 2. p. 54.
Hoff, Von ...... Geognostische Bemerkungen über Karlsbad. 1825.
Berzelius ...... Analysis of the Waters of Carlsbad, in remarks on their origin. Translated from the Swedish. Leipsic, 1823.
Anglada .... Mémoires pour servir, &c. 1827. 1 vol.
Traité des Eaux, &c. des Pyrénées Orient. 1832. 2 vols.
Osann .... Physik-medicinisch. Darstellung der bekannten Heilquellen. 1829.
Boué .... On Thermal Waters. Extracted from various authors. Bull. Soc. Géol. Fr. 1831, vol. 1. p. 95.
Daubeny......... On Thermal Springs. London Review, 1830.

Daubeny......... On Thermal Springs and their connexion with Volcanos. Edinb. New Phil. Journ. 1832.
On the quantity and quality of the Gases emitted from the Bath Water. Phil. Trans. 1833.
On the Thermal Spring near Torre del Annunziata. Ed. Phil. Journ. 1835.
Report on Mineral and Thermal Springs. British Association Reports, 1836.
Goëthe .... Origin of Thermal Waters (Galvanic action). Zur Naturwiss. uberhaupt besonders zur Morphologie, vol. 1. p. 211.
Strecki .... Geog. Abh. v. den Mineralquellen, 1831.
Remarks on a certain kind of organic matter found in Sulphureous Springs. Linn. Soc. Trans. vol. 16, 1831.
Gardner .... On Mineral Waters. Edinburgh, 1834.
Boussingault ... On the Hot Springs of the Andes. Annales de Chemie, 1834.
Longchamp ... Trois Mém. sur les Eaux Minérales. Paris, 1835.
Forbes, James. On the Kissingen Waters. Ed. New Phil. Journ. 1836.
On the Temperature and Geological Relations of certain Hot Springs. Phil. Trans. for 1836.
Bischof .... Vulkanische Mineralquellen. 1836.
Warmelehre. 1837.
Lehrbuch der Chemische Geologie. 1846–47.
Rogers .... Geological Reports on Virginia. 1838.
Bianconi, G. G. De Origine Caloris in Aquis Thermalibus Considerationes quædam. Bologna, 1842.
Junghuhn ...... On the Hot Springs of Java, in his Travels above-quoted. 1845.
Warnsdorff...... Origin of the Waters of Carlsbad. N. Jahrb. f. Min. 1846, p. 407.
Boegner, T....... Die Enstehung der Quellen und die Bildung der Mineralquellen. Francfurt-on-Maine, 1847.

PSEUDOVOLCANIC PHÆNOMENA.

On Burning Springs.

Menard de la Groye. Indication des Feux Naturels, &c. dans divers Pays. Journ. de Phys. 1817, vol. 85. p. 295–314. A catalogue.

On Salses, or Mud Volcanos.

Menard de la Groye. Idée sommaire des Salses. Journ. de Phys. 1818, vol. 86. p. 426.
Pallas .... Travels in the Russian Empire.
Verneuil......... On the Mud Volcanos of Crim Tartary. In the Bull. of the Geol. Soc. of France.
Sir R. Murchison's Russia alludes to the Mud Volcanos of Crim Tartary.
Eichwald ...... Ed. New Phil. Journ. 1833, on Baku.
Junghuhn ...... On the Salses of Java. Magdeburg, 1845.
Dubois de Montpereux. Isle of Taman.

THE END.

LONDON:

PRINTED BY RICHARD AND JOHN E. TAYLOR,

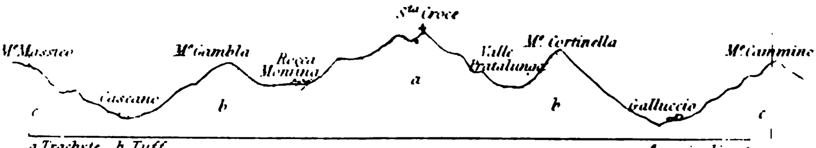
RED LION COURT, FLEET STREET.

ALERE FLAMMAM.

Plate 1

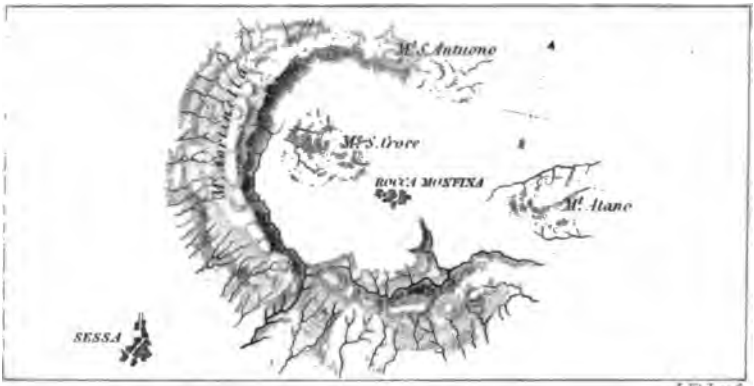
Vesuvius, or Somma, according to Strabo.

Somma and Vesuvius after the time of Pliny.



a Trachyte. b Tuff. c. Appenine Limestone.

Section of Rocca Montina.



J Fisher fc

Ground Plan of Rocca Montina.

Plate 2.

Th. Duclère delin. J.W. Lowry sculp.

TOWN & CASTLE OF MELFI WITH M^T VULTUR BEYOND.

SEEN FROM THE N.E.

Plate 3.

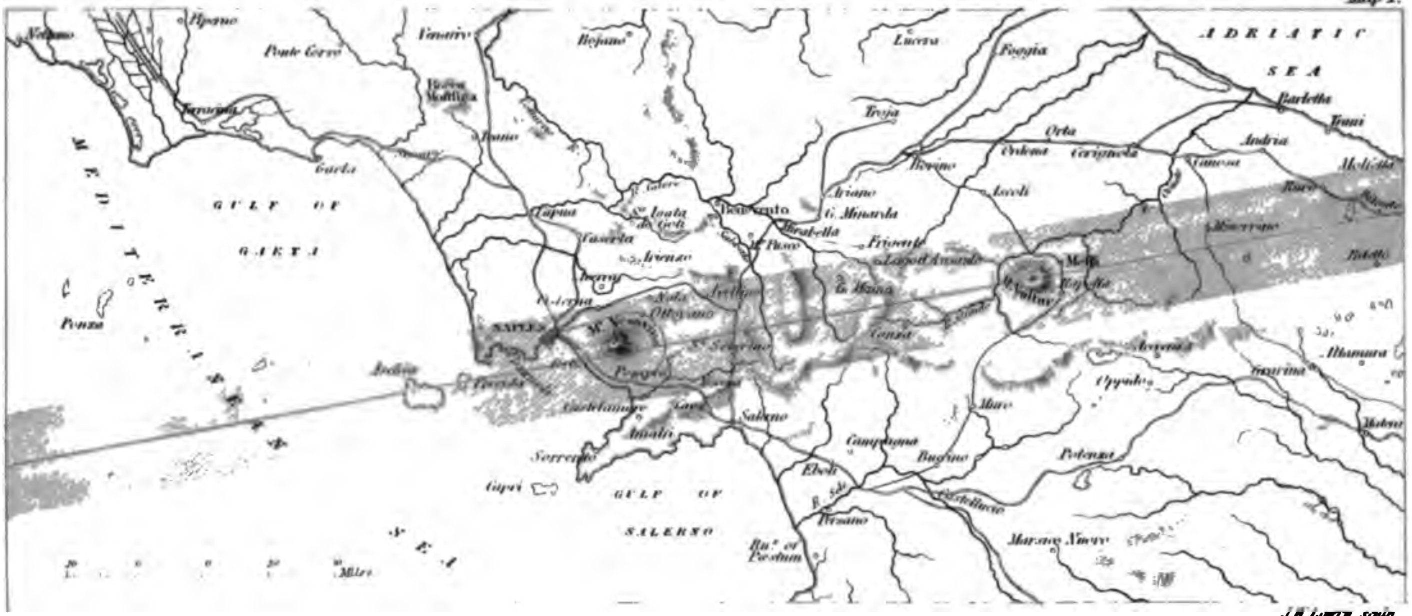
Dufrénoy delin   Rock of Melfi.   Mount Thabor.   aaa. Compact Lava.   bbbb. Volcanic Tuff.   J.W. Lowry sculp

VIEW OF THE TOWN & CASTLE OF MELFI.

Plate 4.

CRATER OF MOUNT VULTUR FROM THE S. W.

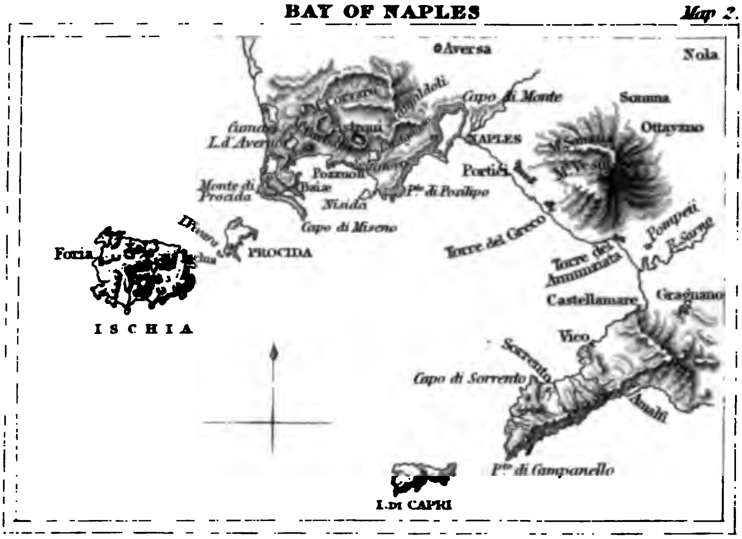
Map 1.



MAP OF A PORTION OF THE KINGDOM OF NAPLES.

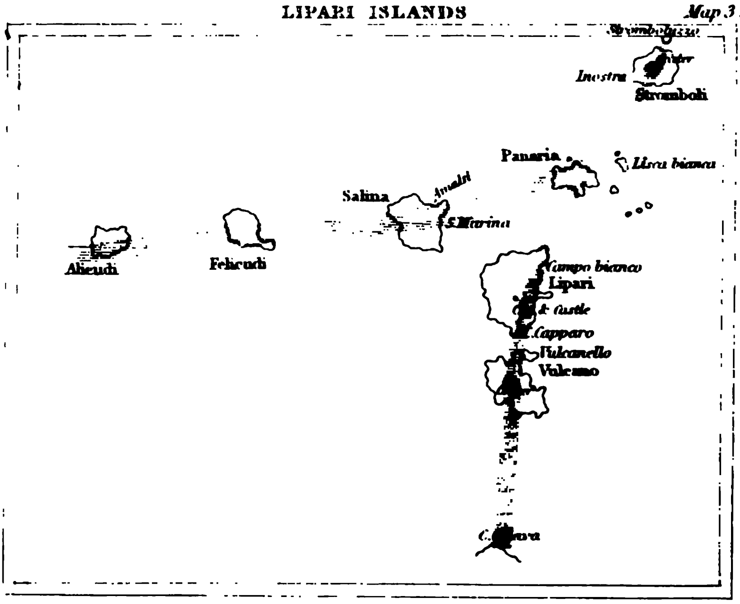
BAY OF NAPLES

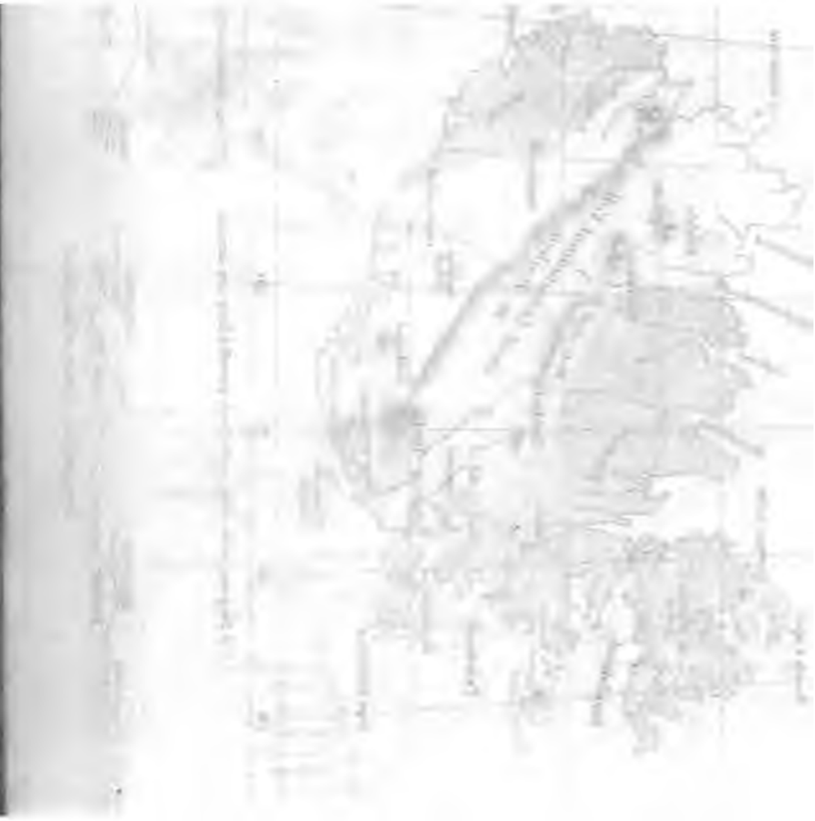
Map 2.



LIPARI ISLANDS

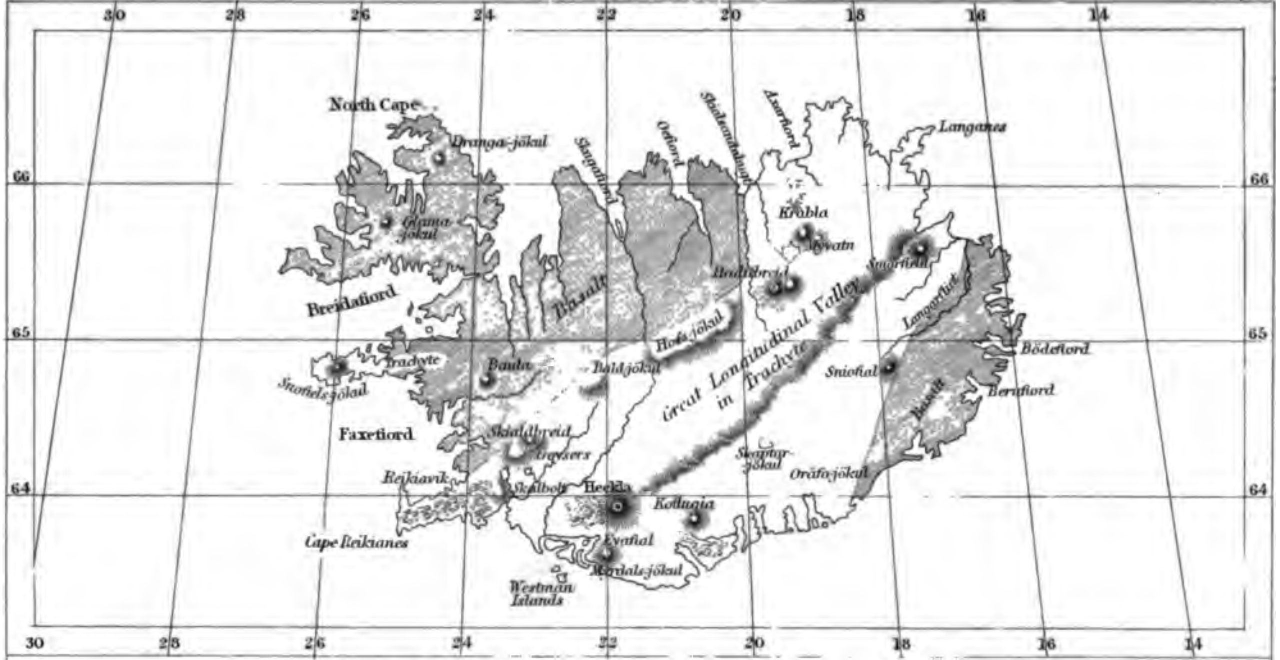
Map 3.





ICELAND

Map 4.



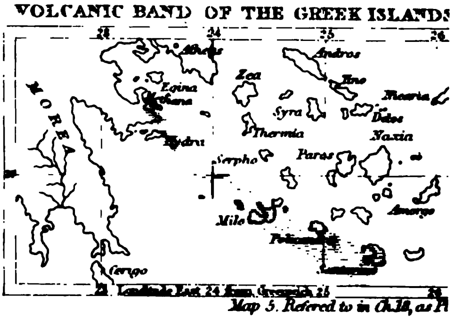
N.B. The parts in the Map marked with parallel lines are basaltic. are streams of Lava.

Longitudinal Section of the Island.

CHART & SECTION OF SANTORIN &c.

Map 6.

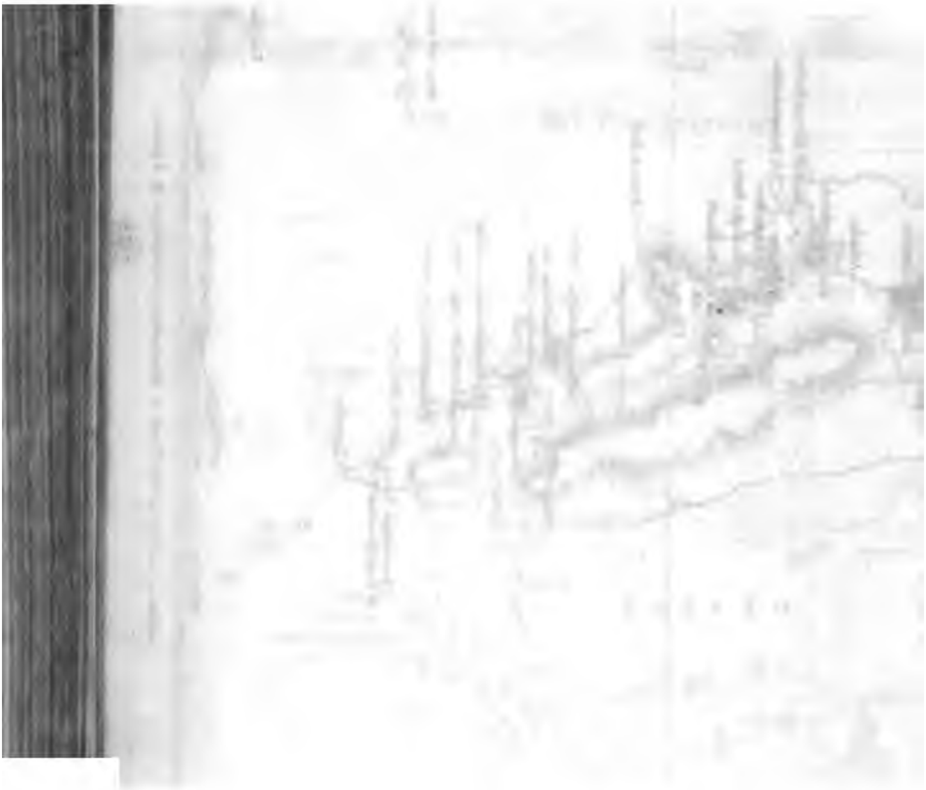
VOLCANIC BAND OF THE GREEK ISLANDS



Map 5. Refered to in Ch.18, as Pl

PALESTINE AND THE DEAD SEA

Map 7. Refered to in Ch.20, as Pl.3

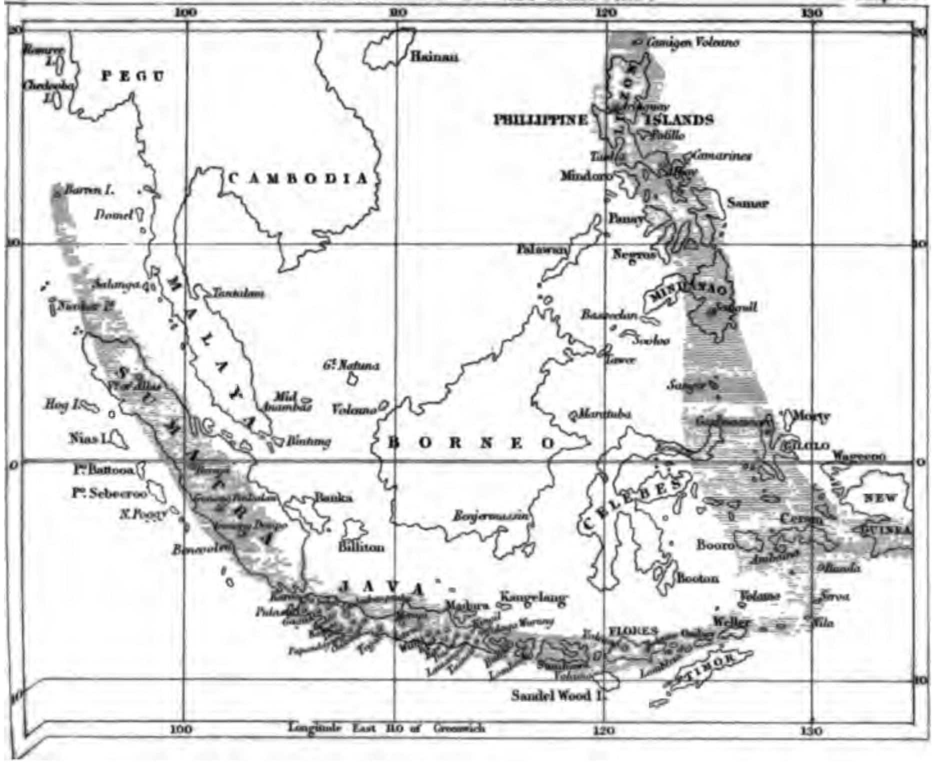


PENINSULA OF KAMTSCHATKA

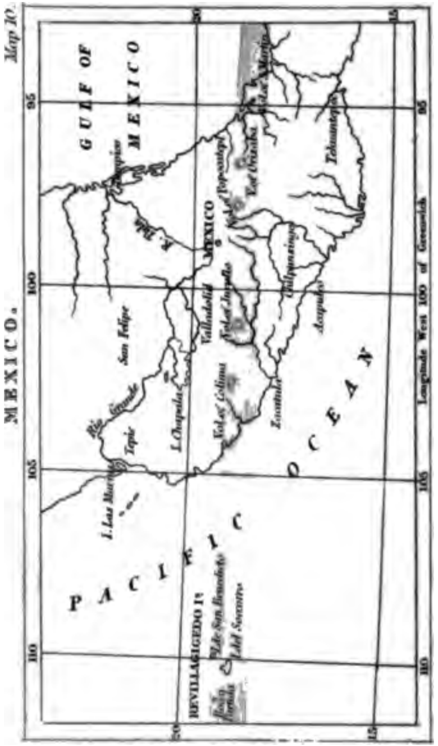
Map 8.

Section of a Part of the North of Kamtschatka, according to M. A. Erman.

VOLCANIC BAND OF THE MOLUCCAS. Map 9.



Map 10.



MEXICO.

Map 11

70
Gaspe Bay
Missouri R.
NEW BRUNSWICK
Quebec
L. St Peter
MONTREAL
Mountains
L. Champlain
VERMONT
NEW HAMPSHIRE
Portsmouth
ALBANY
MASSACHUSETS
Boston
C. Cod
Newhaven
RHODE ISLAND
Philadelphia
ATLANTIC
OCEAN
Chesapeak B.
C. Hatteras
45
40
35
30
100
75
MAP
of the
United States
CANADAS
English Miles